Drilling for Energy in Nevada

Geothermal

Oil & Gas

Nevada Division of Minerals

minerals.nv.gov

Carson City (775) 684-7040

Las Vegas (702) 486-4343

Presented at the Northern Nevada's

Science & Minerals Education Workshop for Teachers

July 17-18, 2018

Any questions can be directed to Courtney Brailo at
cbrailo@minerals.nv.gov

775-684-7046

It may be possible for the Division of Minerals to offer help and answer questions when you are setting up this activity. We can also help with acquisition of needed rock/mineral kits and/or come to your class to give a presentation/introduction of the material, depending on your needs, school location and availability of staff.

Call or email Courtney for more information!

What do these items all have in common?

Oil, Gas and Geothermal Drilling and Production How it works…

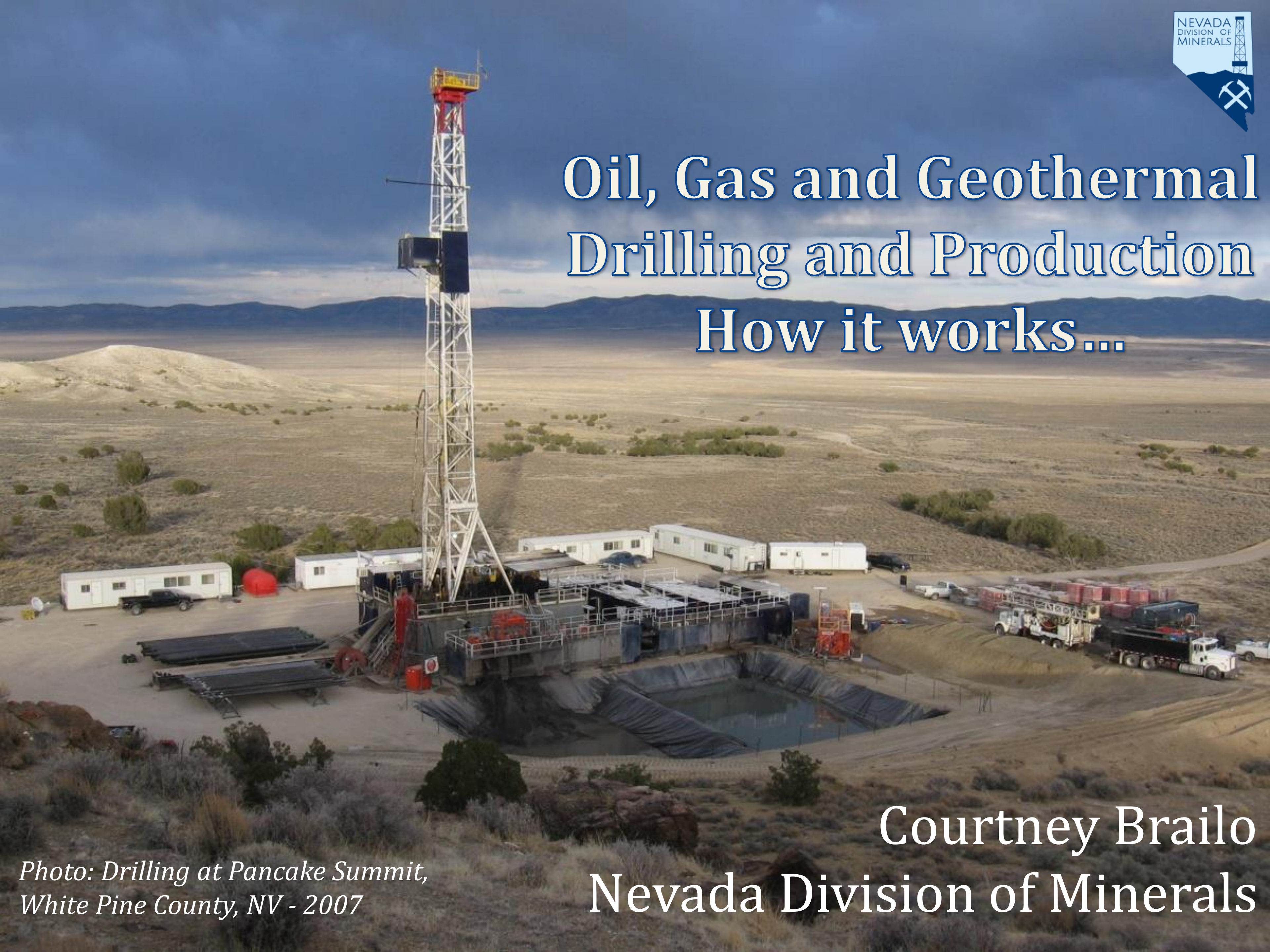


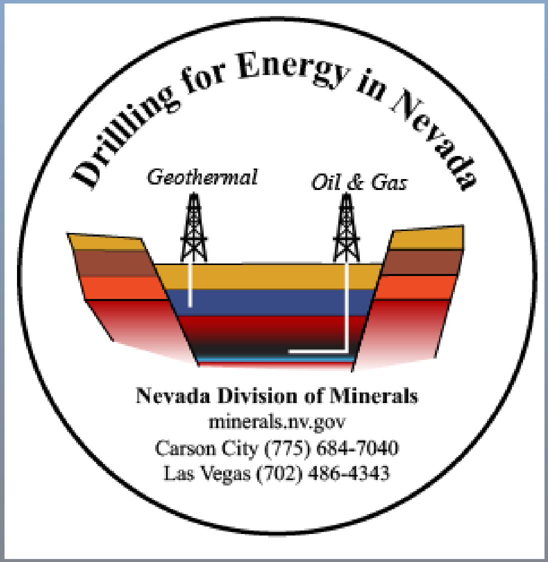
Photo: Drilling at Pancake Summit, White Pine County, NV - 2007

Courtney Brailo
Nevada Division of Minerals

Overview of Energy Exploration

- Oil, Gas and Geothermal Resources

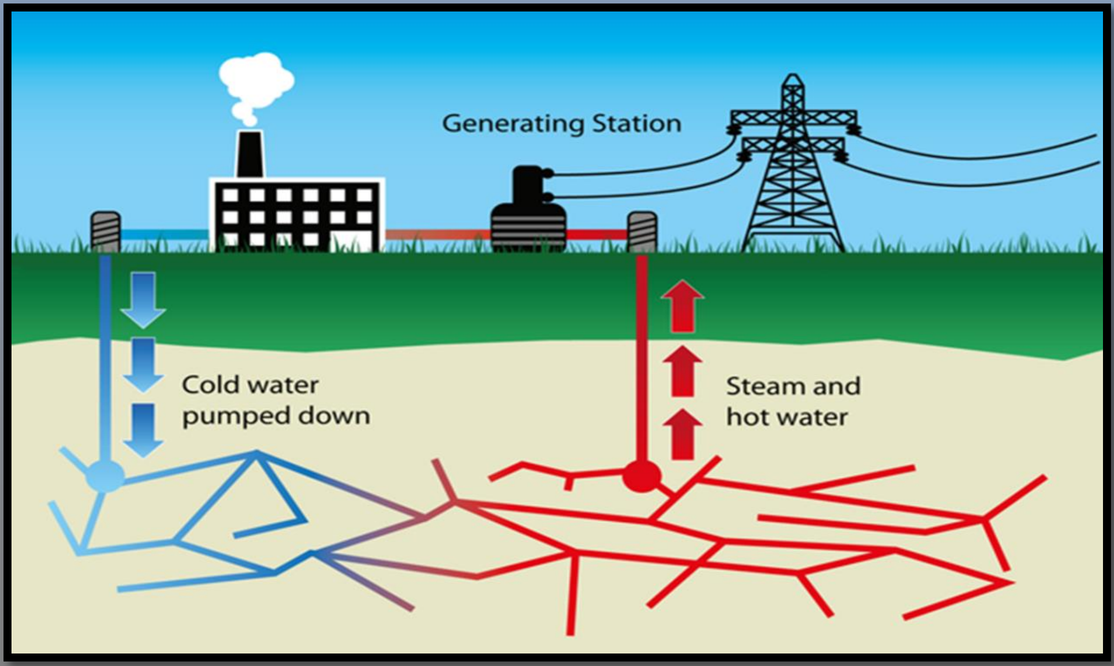
- Exploration & Mapping
- Feasibility Studies
- Production



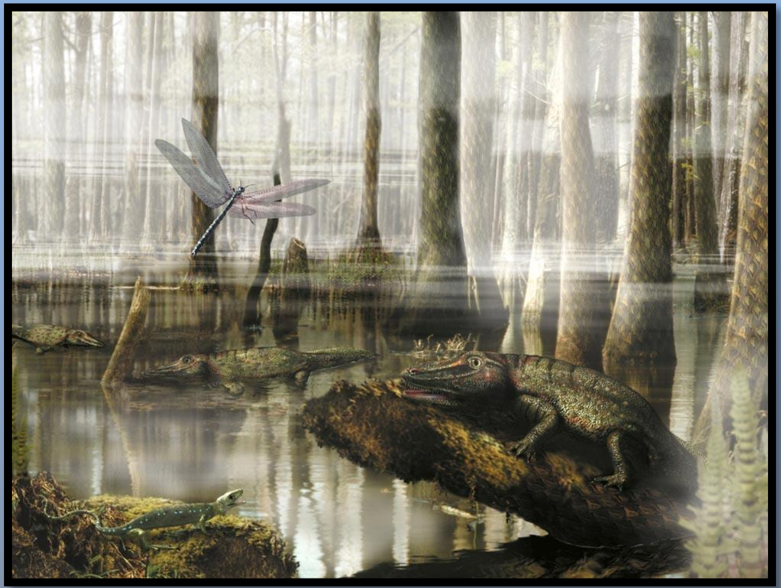
- Nevada-based Exploration Activity

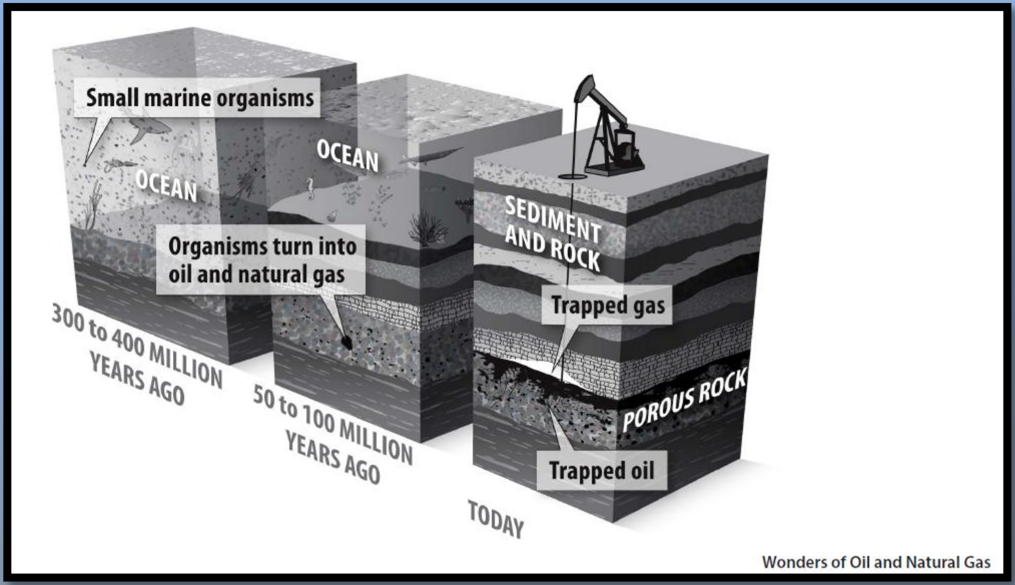
Source of Energy Resources

- Geothermal Energy – Hot water
  - Fractured zones with permeability & heat at depth
  - Hot water turns to steam which turns turbines to generate electricity



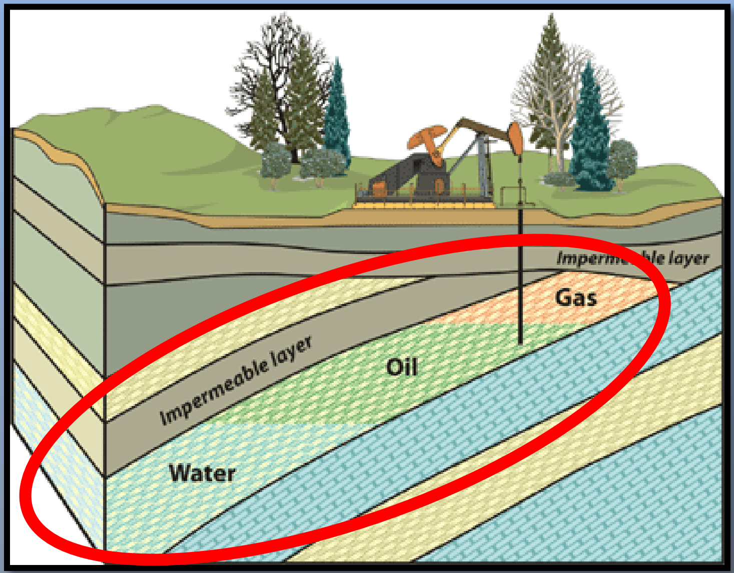
Source of Energy Resources

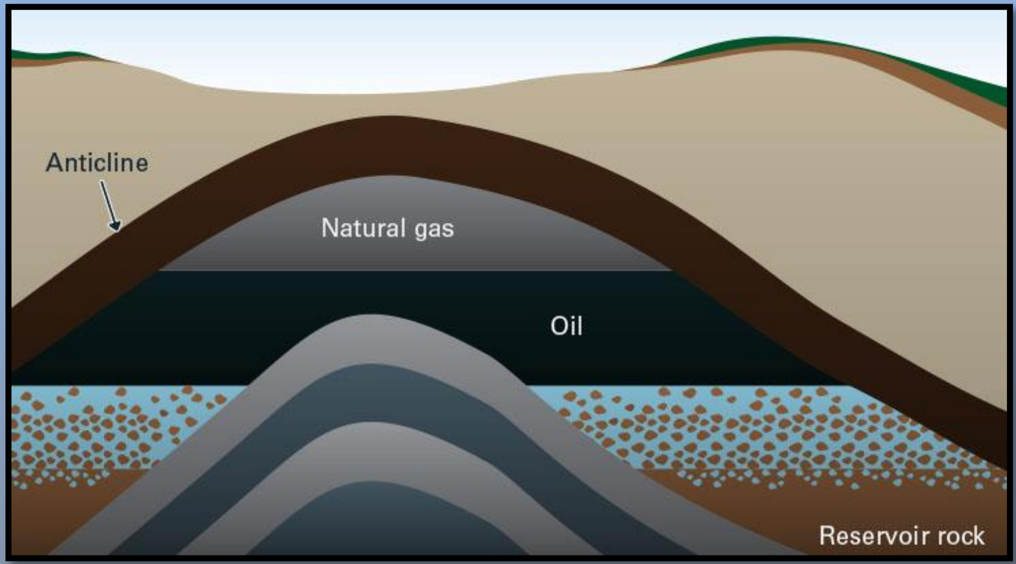




- Oil / Gas
  - Biologically rich environment that was buried for long periods of time
  - Heat and pressure 'cooks' hydrocarbon rich beds

Exploration Phase





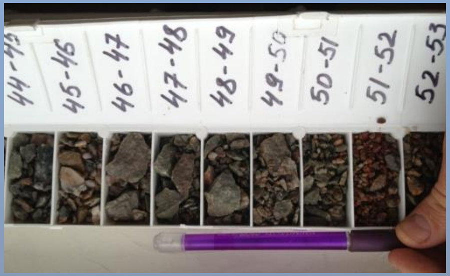
- **Exploration by drilling**
- Does basin have stratigraphy & formations needed to produce the resource?
- In oil need to have a permeable layer that is confined by impermeable layers (trap) to contain resource
- In geothermal is there heat & permeability

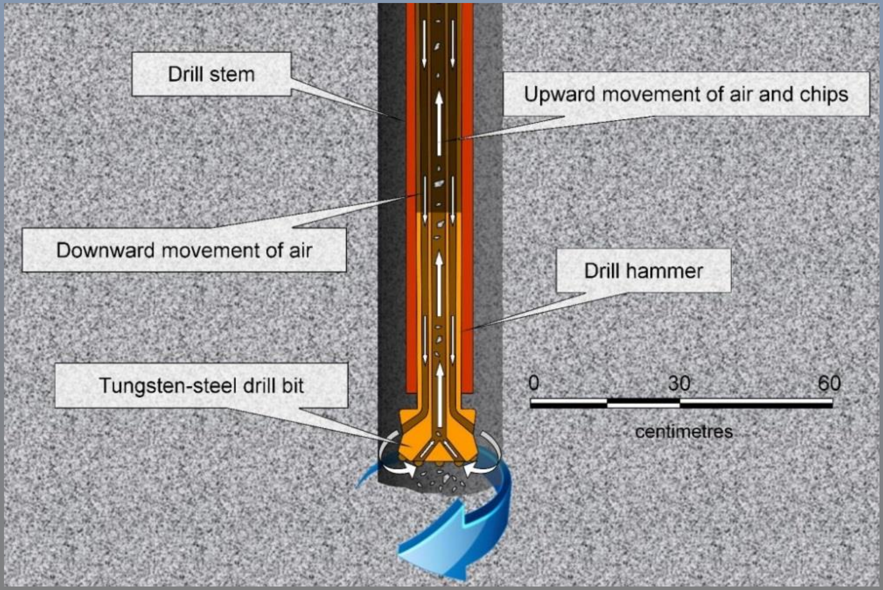
Types of Drill Rigs

- Core Rigs
  - See structure of beds
  - Slower drilling (100’/day)

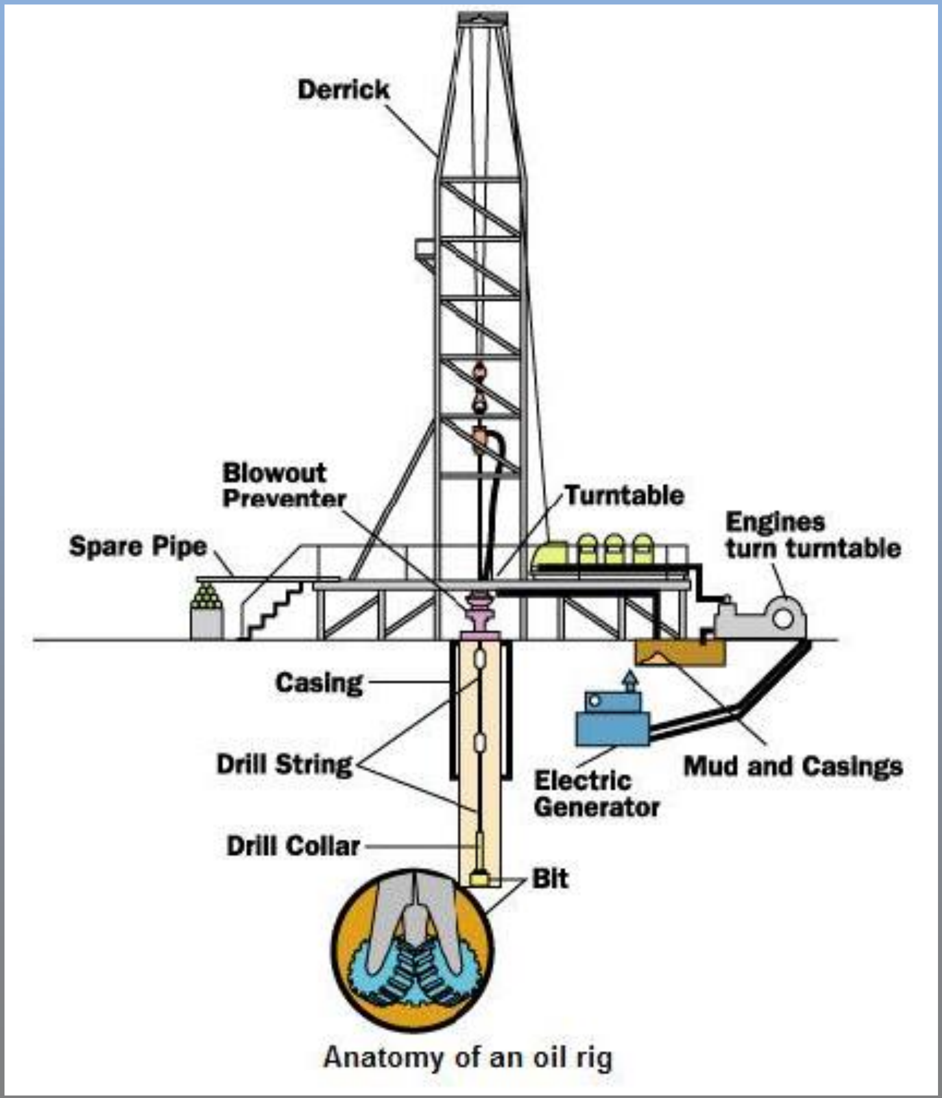
Types of Drill Rigs

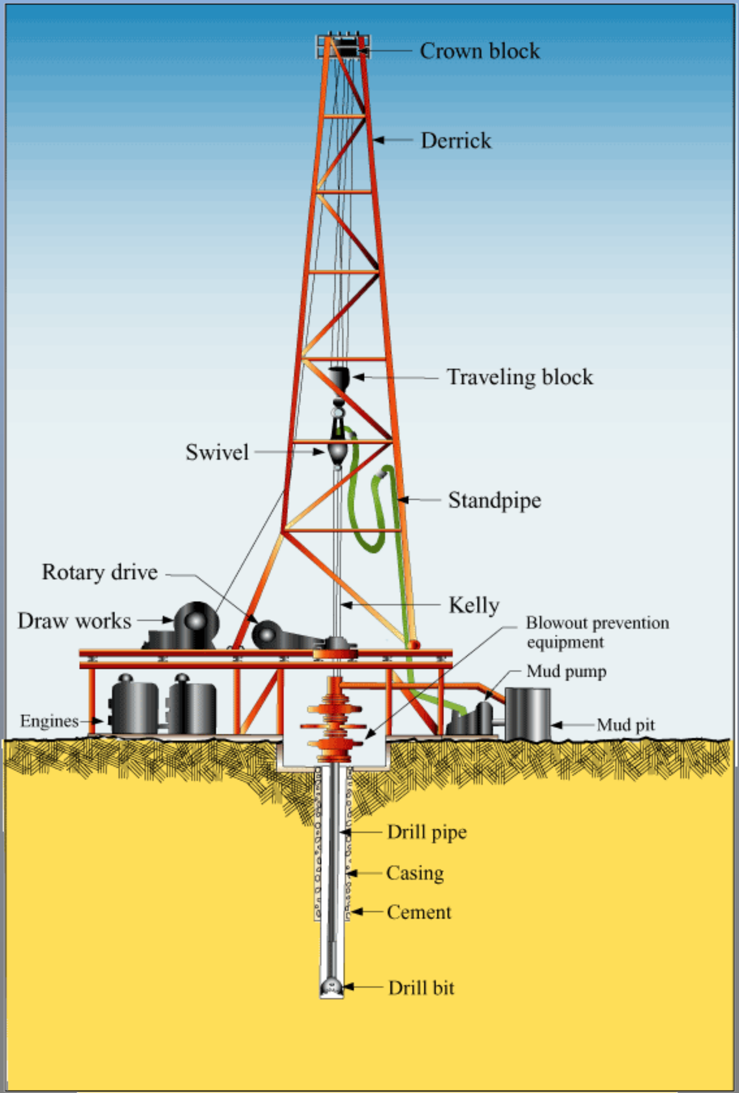
- Reverse Circulation (RC) Rigs - 1000' / day



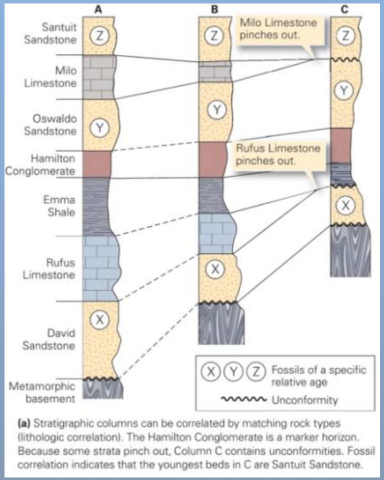


Drilling Operations Schematic

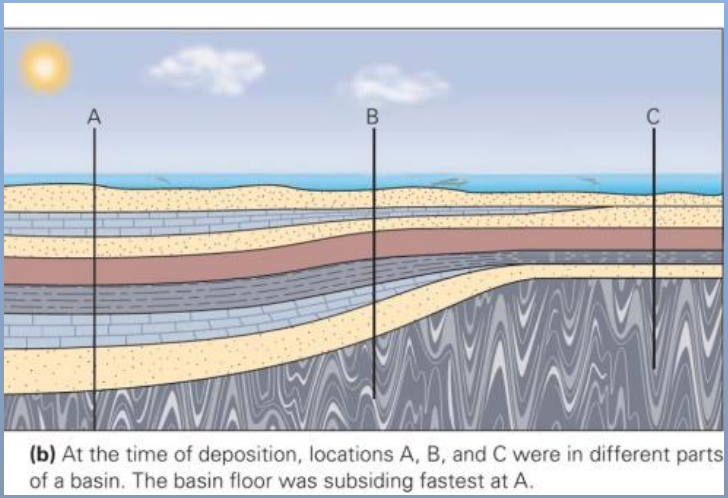




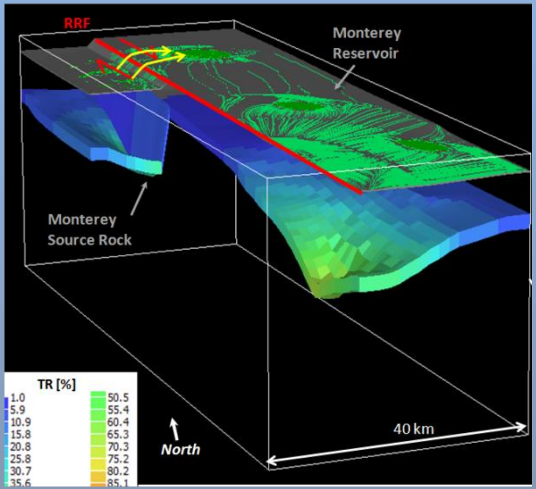
Stratigraphy Interpretations



(a) Stratigraphic columns can be correlated by matching rock types (lithologic correlation). The Hamilton Conglomerate is a marker horizon. Because some strata pinch out, Column C contains unconformities. Fossil correlation indicates that the youngest beds in C are Santuit Sandstone.



(b) At the time of deposition, locations A, B, and C were in different parts of a basin. The basin floor was subsiding fastest at A.



- **Strat Column**
  - Vertical sequence of rocks present at a single location
  - What comes out of the drill string
- **Cross Section**
  - Interpretation, supported by data, of subsurface geology along a profile
- **3D interpretation**
  - Connection of multiple cross sections or interpretation from geophysical techniques to calculate deposit volumes

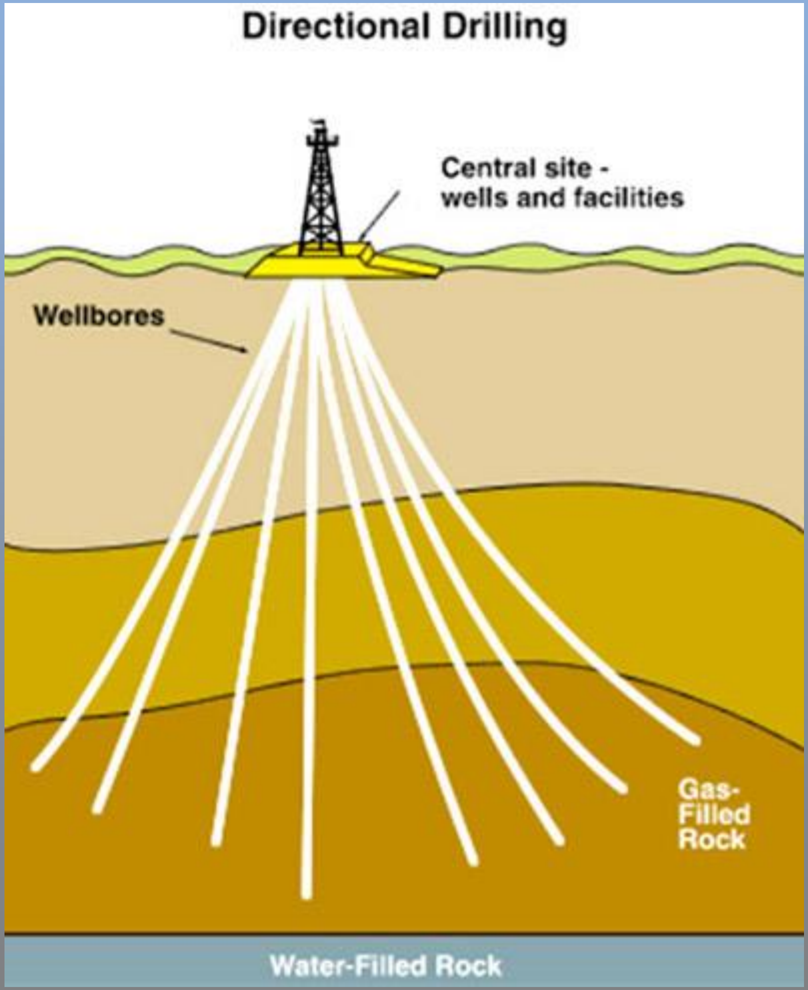
Feasibility Study Phase

Salt Wells Geothermal Plant, NV

- Put together information from exploration phase
- Determine potential size of resource and profit potential
- Market costs – is the deposit profitable?

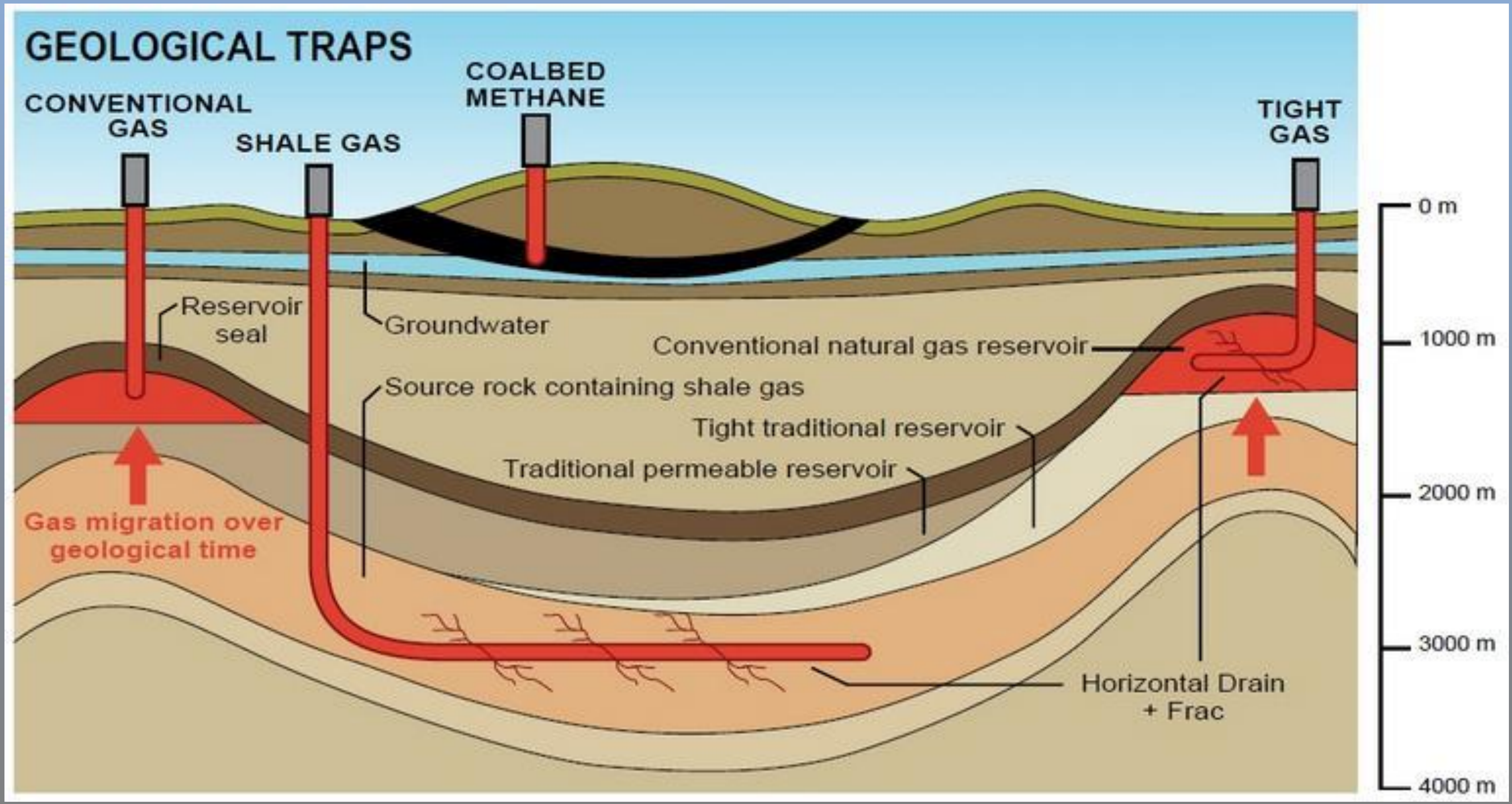
Drilling Plans

- Vertical Drilling
- Directional Drilling
  - Cut across layers too sample stratigraphy
  - Follow stratigraphy to maximize resource production

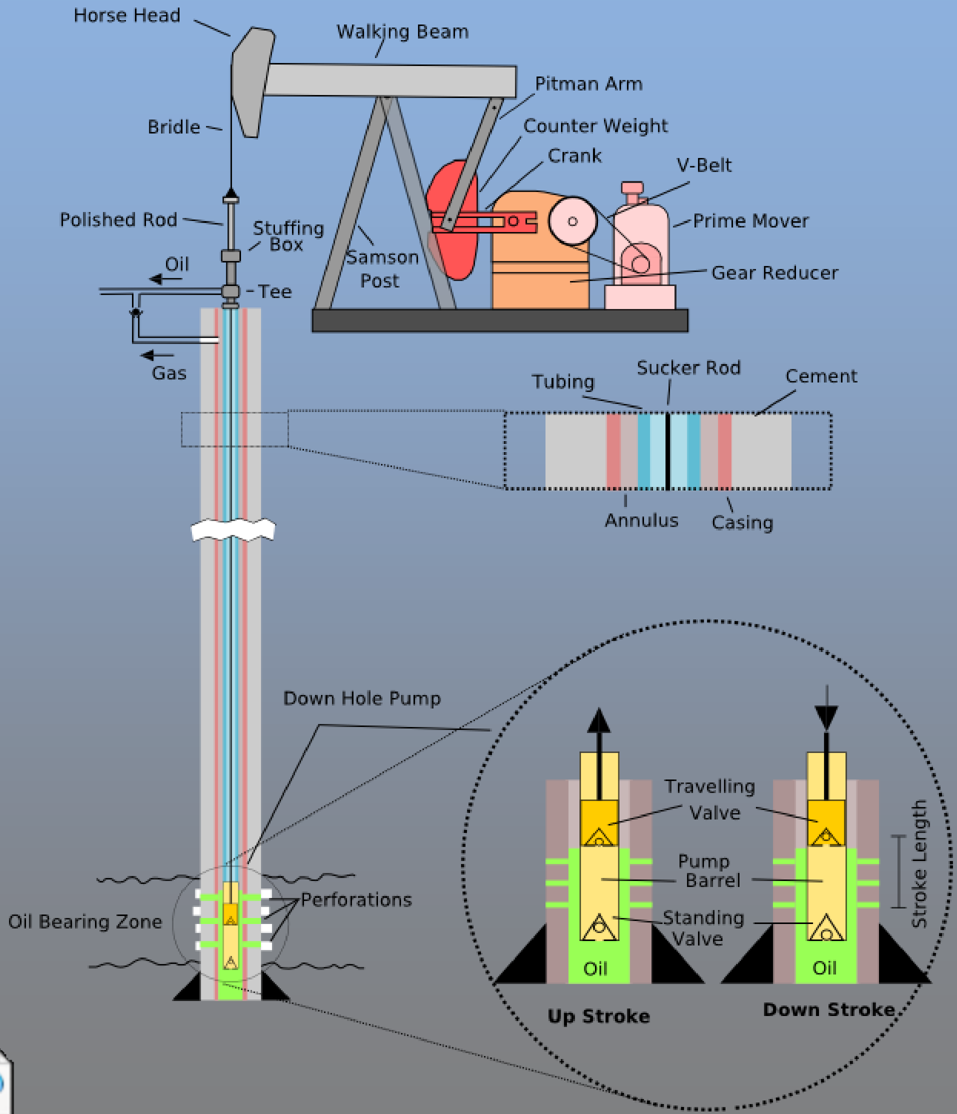


Production Methods

- Drilling Plan based on reservoir characteristics



Production Methods – Conventional



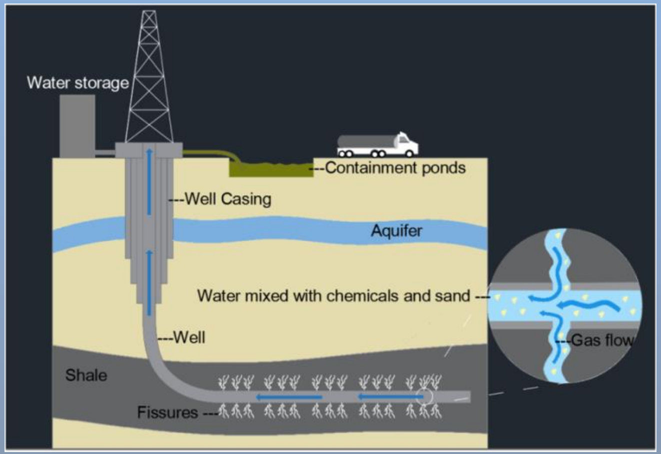
- Flow driven by natural pressure difference
  - high pressure at depth and low at surface
- May include simple pumping of fluids
  - Pump Jacks
  - Left over foot print is quite small

videoplayback.mp4

https://www.youtube.com/watch?v=SFJFiyXTOa0

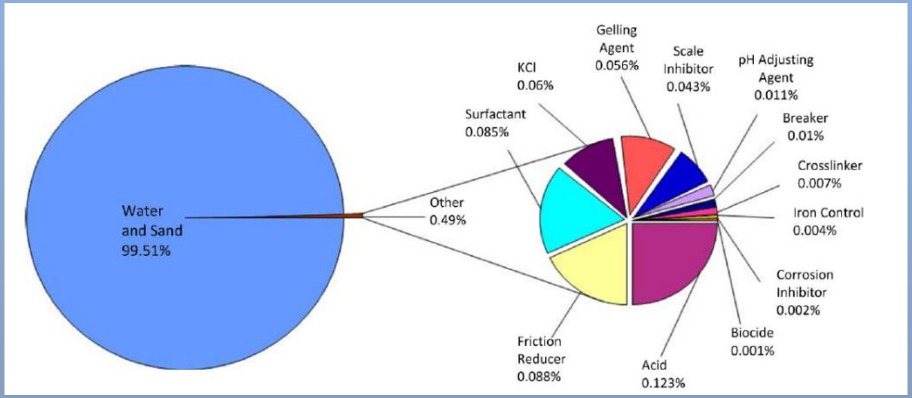
Production Methods – Non Conventional

- Hydraulic Fracturing
  - Increases permeability of rock
  - Occurs after well casing has been set
- Opens up existing fractures in rock by pressurizing well
  - Sand or other bead-like material are introduced as part of the process (in the injected fluids) that keep fractures open
- Development of this technology occurred in response to oil crisis of 1973
  - Experimented as early as the 40s, perfected in late 1990s
  - Eliminated US dependence on foreign oil and gas



Can Fracking Be Environmentally Acceptable? Journal of *Hazardous Toxic Radioactive Waste, 2017, 21(2): 04016013*

Risks and Benefits of Hydraulic Fracturing (or well stimulation for geothermal)

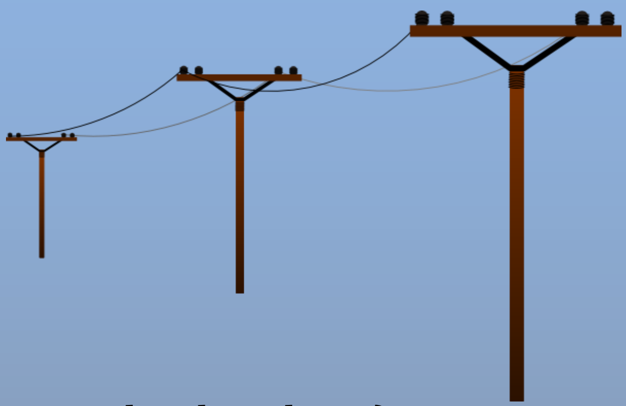


- Hydraulic fracturing happens a great depths (~5,000 – 10,000 feet)
  - Not at the fresh water table – migration unlikely unless well is not operating properly
- Induced seismicity is rare and deep – Caused by waste water injection
  - Ground needs to at critical stresses to induce
  - May affect timing of earthquakes, but not occurrence
  - Can be controlled by controlling rate of injection
- Uses a lot of water – can be an issue in drought or arid regions
  - Many wells starting to recycle waste water
  - About an acre-foot of water per well in Nevada
  - One alfalfa pivot uses 500 acre-foot per year
- Chemicals used must be approved and makes up less than 1% of total fluids

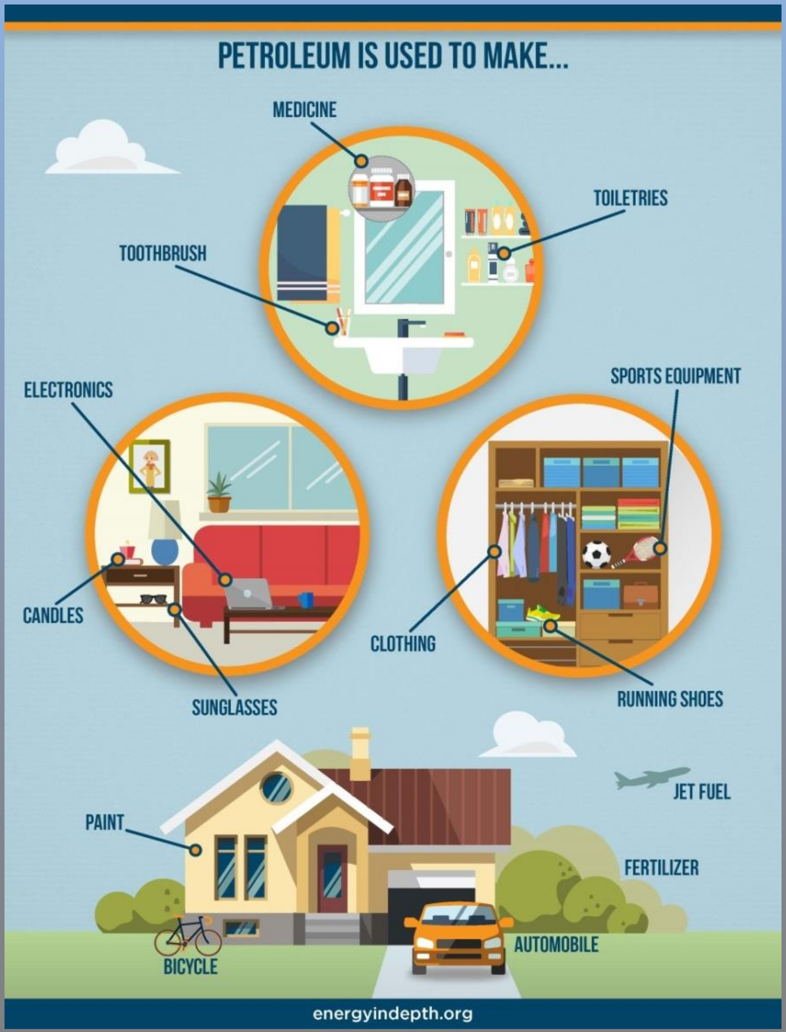
Risks and Benefits of Hydraulic Fracturing (or well stimulation for geothermal)

- **Natural gas creates electricity that is 50% or more cleaner (in terms of CO_2) as compared to coal**
- **Exploration is getting quieter and more efficient with new technology – use of a single drill pad and horizontal drilling has helped reduce the environmental impact of drilling**
- **Without this process we wouldn't have access much of the worlds hydrocarbon or geothermal resources!**
- Risks can be minimized with regulations – well construction, casing specs and limiting rate of reinjection

Oil, Gas and Geothermal Provide:



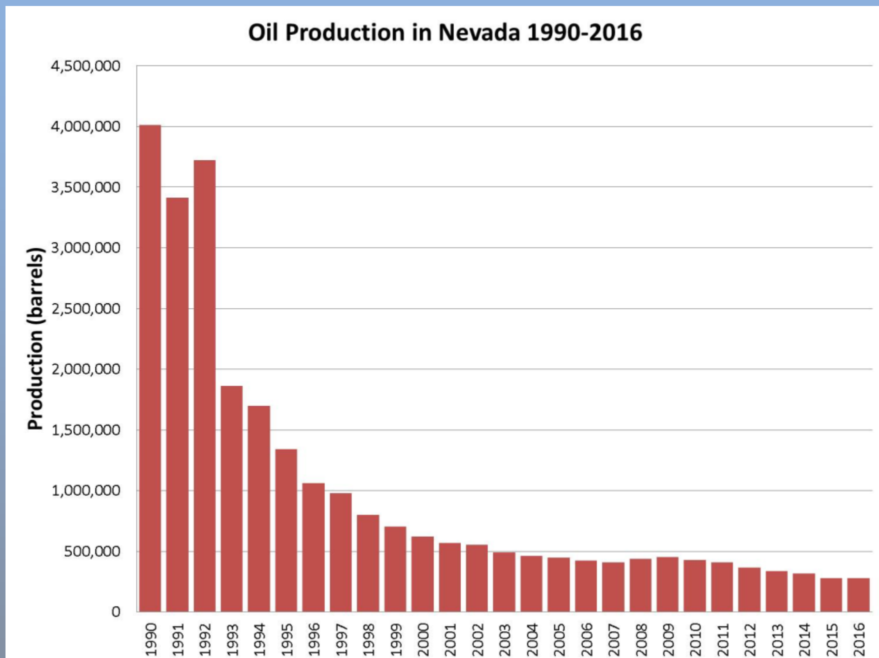
- Energy (geothermal, oil and gas)
- Gasoline & natural gas (cars homes)
- Waxes
- Plastics (everything!)
- Synthetic Fibers (like polyester)
- Dyes
- Detergents
- Asphalt
- **Jobs!**
  - Over the course of well drilling it is estimated that ~430 people from 150 occupations are employed in some part of the process.

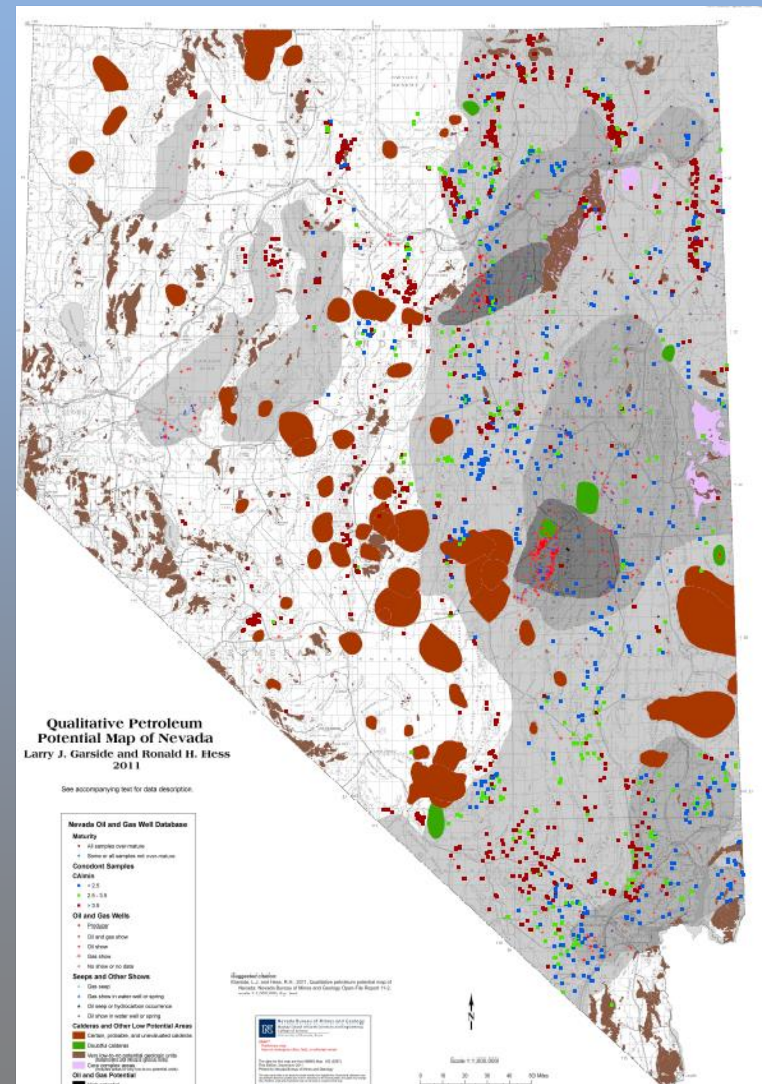


Long Term Resource Use and Reclamation

- Utilize all reserve potential
  - Reinjection of fluids (geothermal)
  - Life of an oil/gas well can vary from a few years to many decades
    - Can clean out oil reservoir to maximize production by reinjection of fluids
  - Plugging/Abandonment
  - When wells are no longer needed, or if a resource is not profitable
  - Required by federal and state law

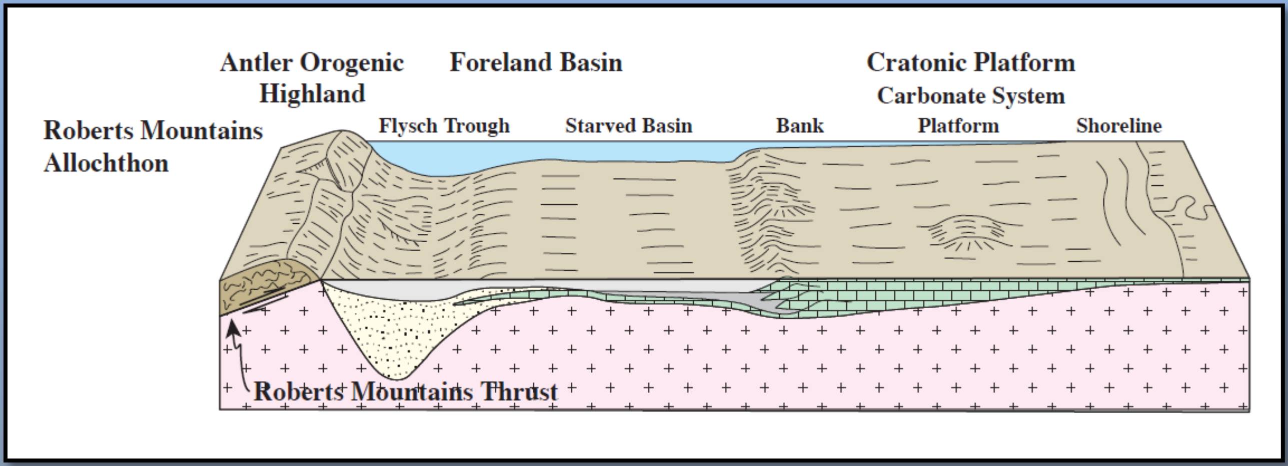
Nevada's Oil/Natural Gas Resources

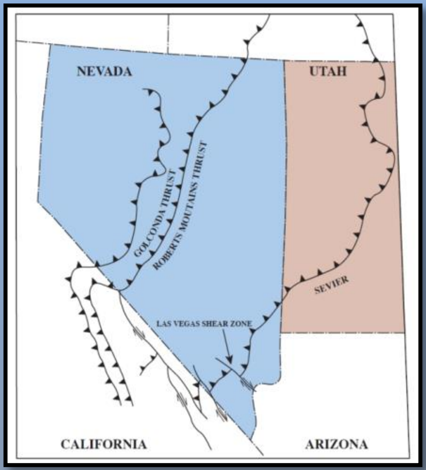




- Currently (2018) have five Oil/Gas producers in the state
- One exploration hole was drilled in 2017

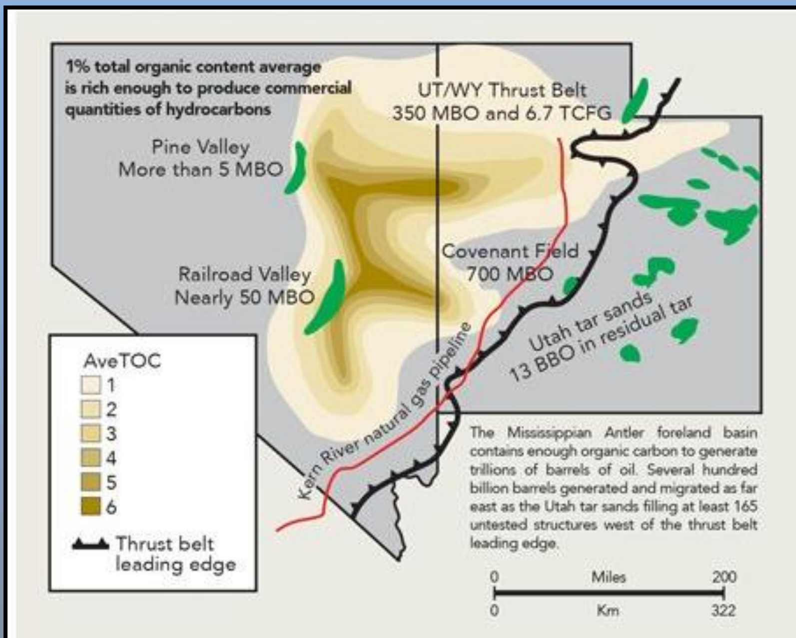
Why do we have oil?
Nevada Cross Section

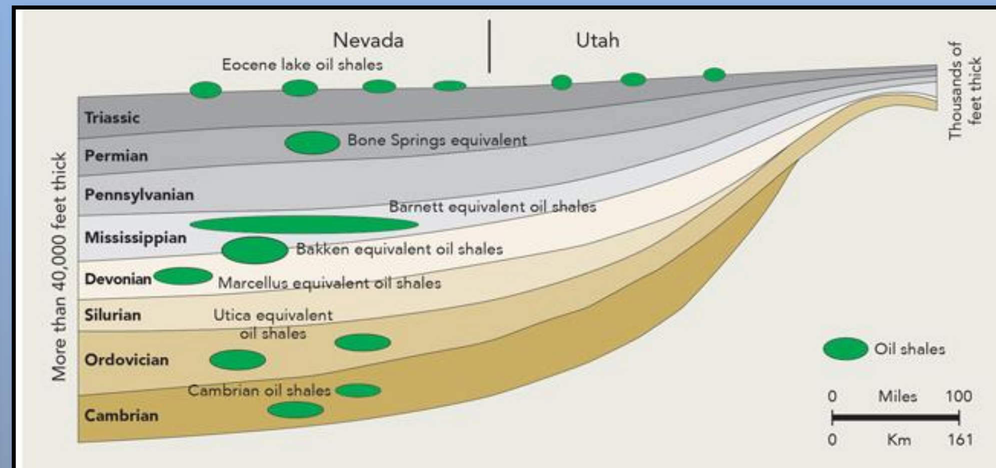




- Many stages of mountain building events that built the west
- Basins fill as they deepen with sediments from mountain range uplift
- Often basins covered by large inland seas which were filled with organic material

Great Basin Shales



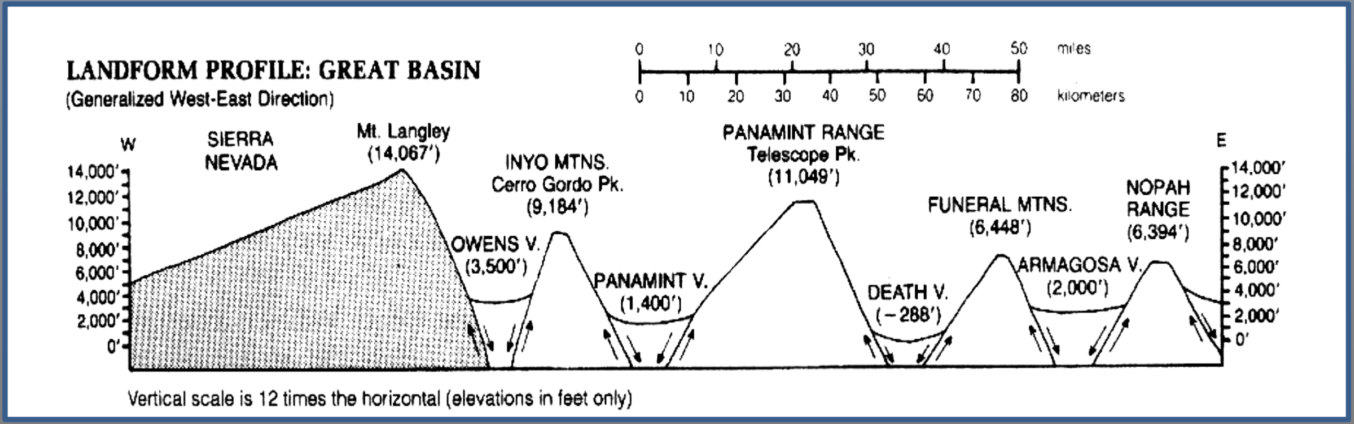


Oil & Gas Financial Journal, Jan. 2017

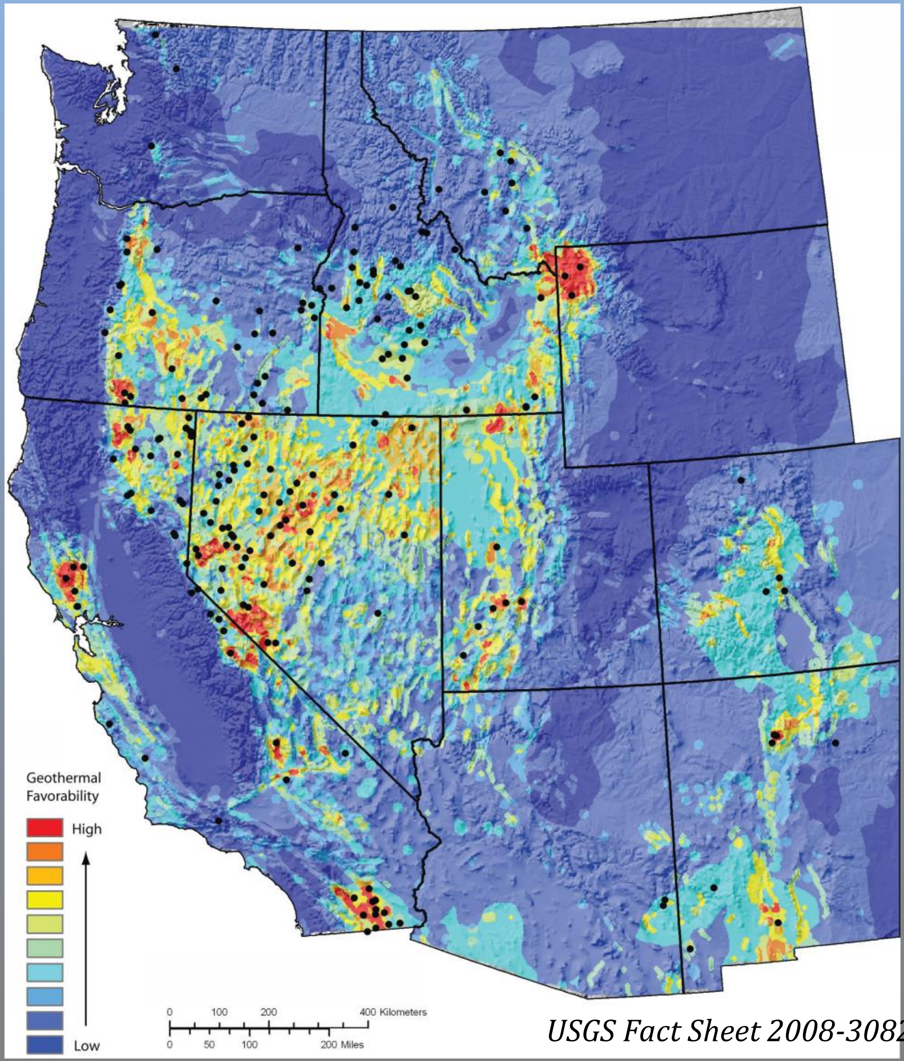
- Nevada's oil reserves consist of limestone from the inland seas and associated shales

Geothermal - Basin and Range Extension

- Extension leaves crustal thinning that allows heat from the mantle to be closer to the surface
- Faulting from this extension (along with some Walker Lane/San Andreas style strike slip) has allow for fluid travel



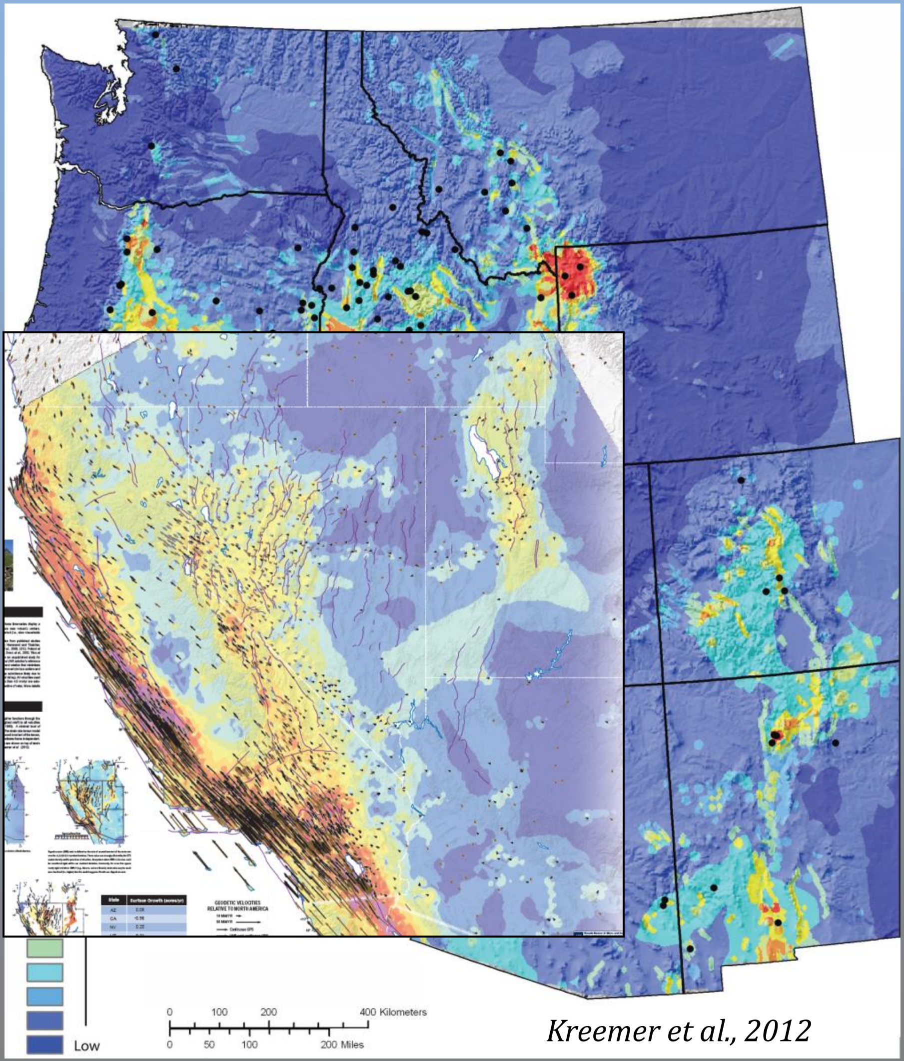
Geothermal Favorability Map



USGS Fact Sheet 2008-3082

- Nevada has most hot springs in the US
- Largest source of renewable energy in the state
- Second largest producer in country

Geothermal Favorability Map



- Nevada has most hot springs in the US
- Largest source of renewable energy in the state
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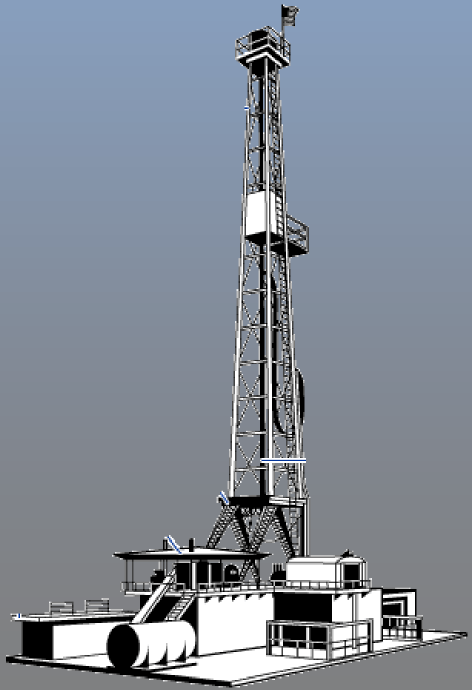
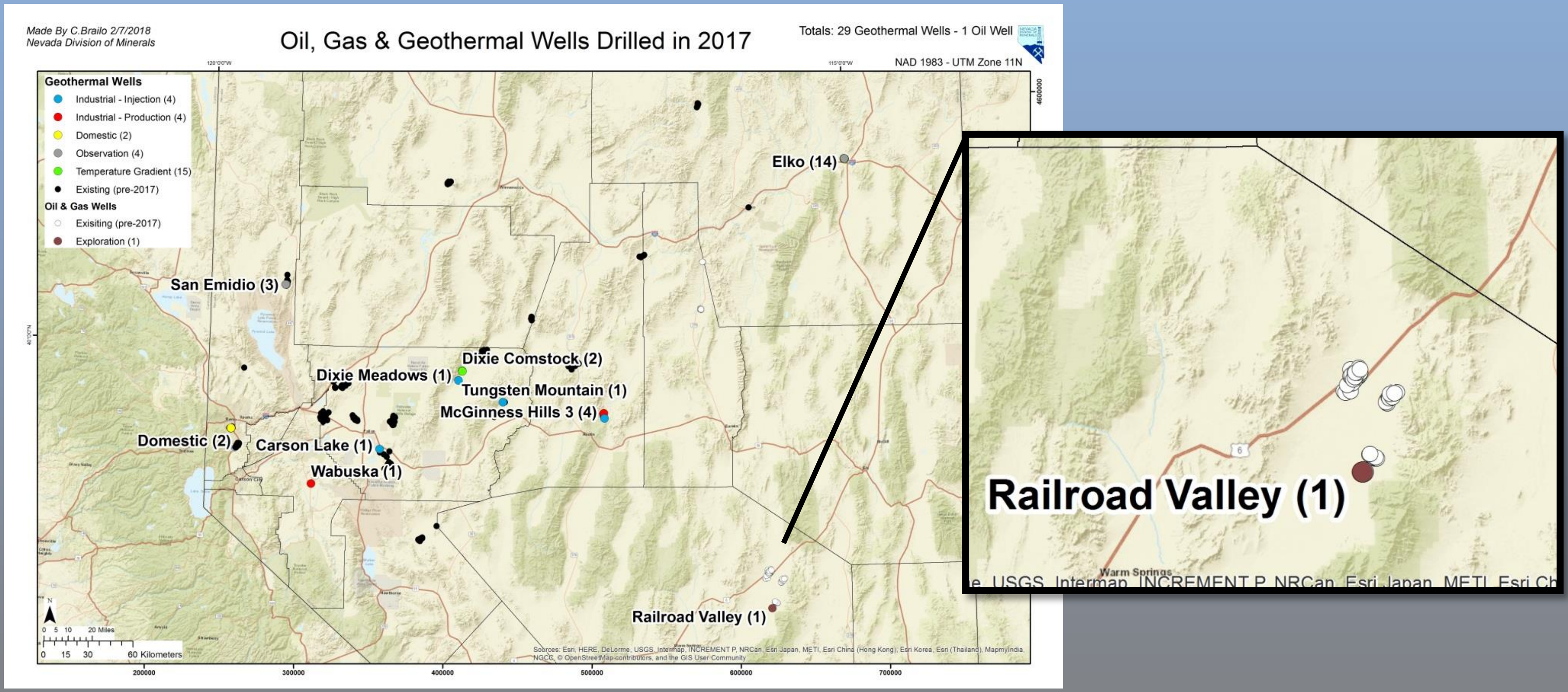
We are going to explore for oil & gas in Nevada!

- Activity will go through the process of identifying a reserve from exploration to production using a Nevada-specific example

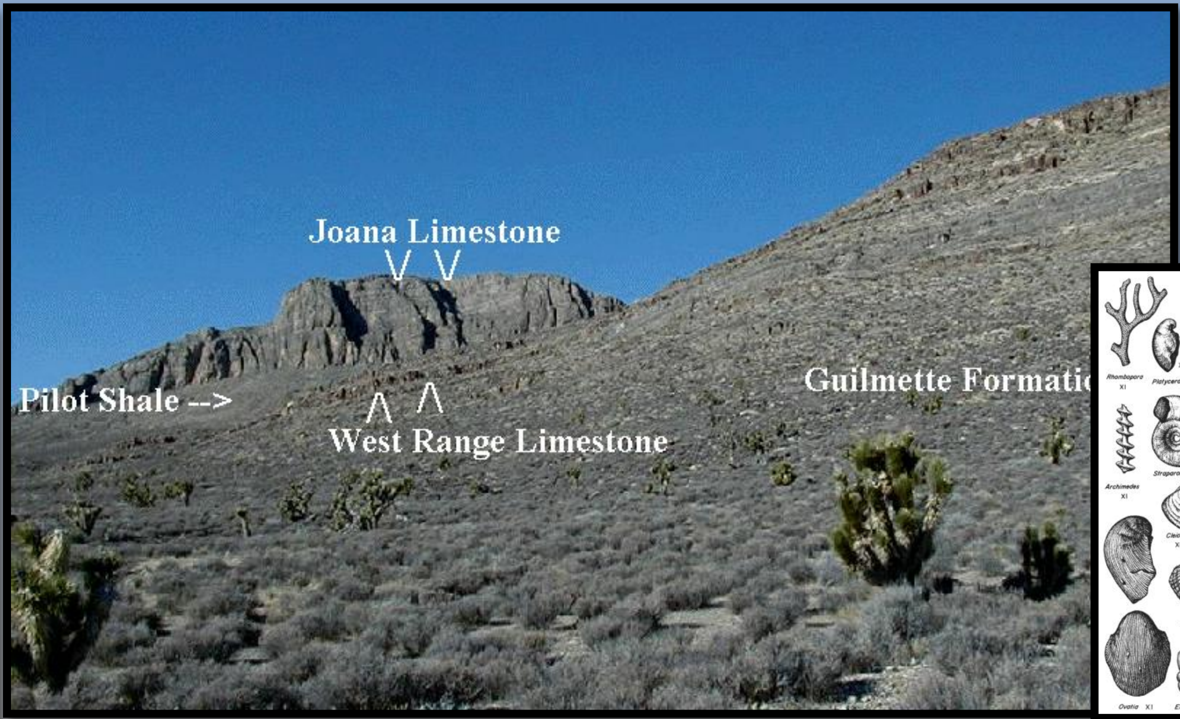


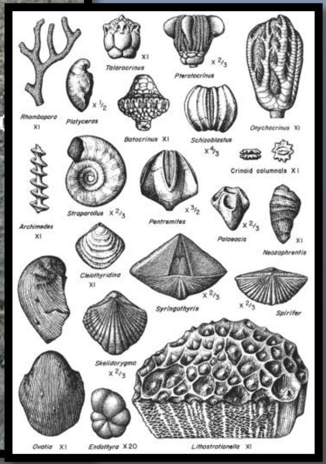
Recap – Railroad Valley



Recap - Joanna Limestone

- Fossil types include echinoderm, bryozoans, foraminifera, algae, and crinoids



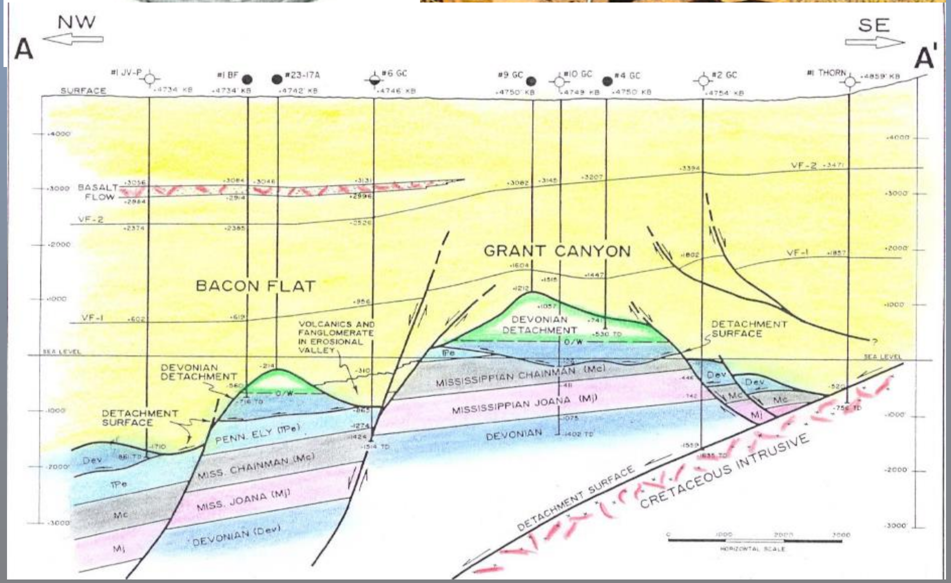


Hosts mineralization within deposits (post Carboniferous-age)

Recap – Railroad Valley

- 1954 - First oil discovered in RRV (by Shell)
  - 1949 PhD thesis paper by Walt Younquist, that found oil pockets while studying cephalopods in the shales here
- Now the basin has 9 recognized oil fields have produced 47million barrels of oil
- **The Joanna Limestone** is the underlying (bottom) member of the reservoir rocks and are surrounded by the source and trap shales
  - Variable permeability, can be poor to good, but also increased by fracturing

From: Oil Fields in Railroad Valley Nevada Louis C. Bortz1 Search and Discovery Article #20376 (2016)** Posted December 19, 2016*



Johnson, E.H., 1994, Geologic and Seismic Analysis of the Bacon Flat-Grant Canyon area, Nye County, Nevada: in Oil fields of the Great Basin, Nevada Petroleum Society, Reno, Nevada, p. 227-240.

Follow up & other resources

- Energy Resource Activities – all ages/grades
  - http://oogeep.org/teacher-students/educational-materials/
- Hydraulic Fracturing activity
  - https://www.airwatergas.org/resources/curriculum/make-a-fracking-model-activity/
- Wonders of Oil & Natural Gas Activity
  - http://www.need.org/files/curriculum/guides/wondersofoilandgas.pdf

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Activity

Version One – Blank Template

Includes: four rock identifications from hand samples, five rock identifications from descriptions only, a blank geologic map and the construction of a well log from blank graph paper.

Rocks required by this activity have been provided in Minerals/Rock Kit during the Minerals Education Teachers Workshop hosted by the Nevada Mining Association and the Nevada Division of Minerals

Contact ndom@minerals.nv.gov or see https://www.nevadamining.org/mineral-education-workshops/ for more information.

Activity Created by C.M. Brailo, Nevada Division of Minerals 2018-07-09

Drilling for Energy in Nevada
Classroom Activity

Created for the Nevada Mineral Education Workshop
by C.M.Brailo – Nevada Division of Minerals, 2018

Purpose/Introduction: Nevada is a state plentiful in energy resources. These resources include geothermal, solar and wind energy fields that exist throughout the state. Nevada also has oil and gas resources and has a robust history of successful oil wells. During the 1980s one oil field in southeastern Nevada included some of the highest producing wells in the country for its time, although now technologies and reserves in other states, such as North Dakota and Texas, have greatly surpassed Nevada's production. Nevada has produced over 53,000,000 barrels of oil throughout its history. The state currently hovers around 27th out of 30 oil and gas producing states in terms of barrels of oil and gas produced, with the majority of the wells located in rural parts of the state. Many states rely on hydraulic fracturing technology to successfully produce oil and gas from their wells. In contrast, Nevada has very little hydraulically fractured wells, three fields in total ever utilized the technology, and no horizontally drilled wells. However, should new wells choose to use the technology here the state has passed some of the strictest hydraulic fracturing laws in the nation, with key emphasis on well construction that ensures the protection of fresh water aquifers that exist at relatively shallow depths as compared to the oil and gas targets. This activity will highlight the process of exploration and extraction of oil with a Nevada-specific case example and hands-on activity.

For more information on the history of oil production in Nevada and currently Nevada oil and gas production statistics see the Nevada Bureau of Mines and Geology (http://www.nbmg.unr.edu/Oil&Gas/HistoricalSummary.html) and the Nevada Division of Minerals (http://minerals.nv.gov/Programs/OG/OG/) websites.

Materials:

- Rock Identification Kit
- Nevada-specific Rock Samples
- Outcrop Map
- Colored Pencils
- Rulers
- Knox Gelatin
- Syringe and Tubing
- Plaster of Paris
- Empty Water Bottles

Activity with Instructions:

Part I. Rock Identification: you are hiking through the foothills in eastern Nevada. You find an interesting rock in one of the washes. Use the following chart to identify your rock.

Rock Location	**Color**	**Grain Size**	**Texture: Layered or Massive?**	**Unique Properties**	**Igneous, Sedimentary, Metamorphic?**	**Rock Name**
1: Lat: 38° 32' 22" Lon:-115°26' 06"						

You become curious if there are other rocks like this around in the area. You proceed to identify rocks from different places around the valley (collecting and documenting the locations of the samples you collect). The following chart includes descriptions of rocks you found at type-localities (places where you found the best specimens and good examples of the deposit). **Identify your rocks by filling in table below.**

Rock Location	**Color**	**Grain Size**	**Texture: Layered or Massive?**	**Unique Properties**	**Igneous, Sedimentary, Metamorphic?**	**Rock Name**
2: Lat: 38° 28' 51" Lon: -115° 24' 07"						
3: Lat: 38° 36' 43" Lon: -115° 23' 45"						
4: Lat: 38° 32' 54" Lon: -115° 21' 40"						
5: Lat: 38° 25' 33" Lon: -115° 28' 15"						
6: Lat: 38° 23' 24." Lon: -115° 34' 01"						
7: Lat: 38° 32' 10" Lon: -115° 31' 23"	Mixed clasts, grey, brown, tan and black	Varied sands to cobbles and boulders	Clasts range from massive to layered	Faulted – large range of clasts – has many drainages and hummocky terrain	Unconsolidated Sediments	
8: Lat: 38° 29' 50" Lon: -115° 37' 55"	Light tan to white	Fine	Layered	Smooth surface in center of basin, with evaporates	Unconsolidated Sediments	

Faulting in alluvial sediments at Railroad Valley (type locality 8 above)

Are there rock units that could be profitable for oil, natural gas or mineral exploration?

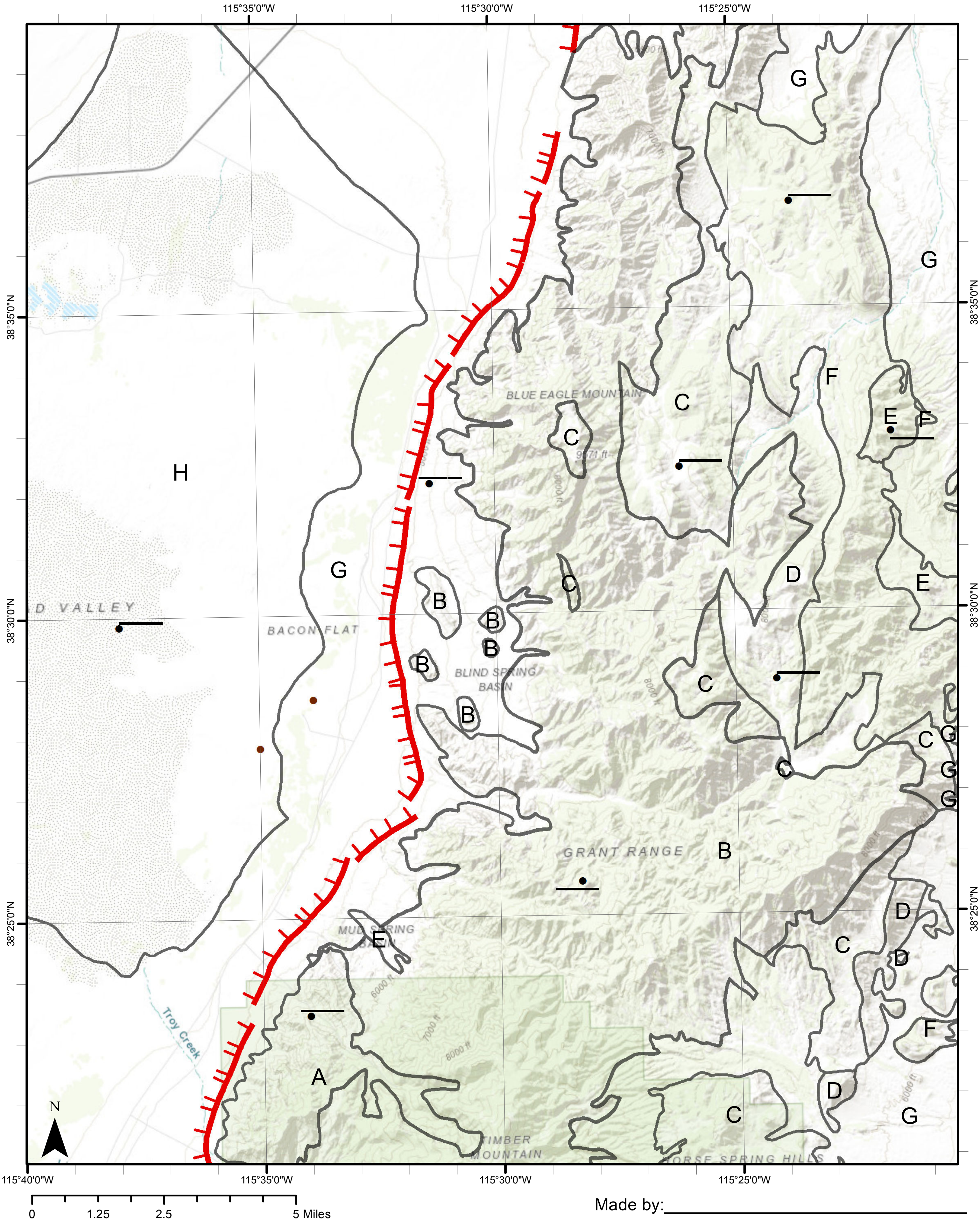
Part II. CREATE A GEOLOGIC MAP

Further mapping (boots on the ground!) leads to the discovery of geologic contacts, or boundaries, for each of these deposits. You even find map out a major fault in the area (see photo above). The attached map depicts these boundries. The geologic rock units are labeled by the letters A-I on the map.

On the provided map, locate and label where the type locality rocks (best representive of the geologic unit) were found that you identified in the table in Part I.

Pick a color to represent the rock type for each of your geologic units and color in the boundaries for each rock type to make a professional looking geologic map. You will eventually need a legend for your map, but we will build it after we have more information about the rock units.

Railroad Valley Geologic Map



Made by:__________________________________

Is it possible that the rock outcrops you have mapped could be located deeper in the basin where they may have been heated enough to produce oil or gas? What evidence do you have to support your conclusion? *Hint: Think about structural evolution of the NV basin and features you have found during mapping.*

How might you find out more about these rocks at depth?

Part III. Well Logs

You decide to drill some exploration holes and see what lies in the basin! You do the land research and find out the area you are interested in is owned by BLM. You find investors that believe in your resource potential, you obtain a lease from the BLM, and obtain BLM and State permits to drill. This also requires that a bond be put in place to ensure proper plugging and reclamation of the well is completed after drilling.

You drill the well at: Lat: 38° 27' 49" Lon: -115° 34' 59". This location is plotted on the map and the well log on the attached page shows your results.

Do you find similar rock units in the well logs that you identified during the geologic mapping stage?

Are there any signs of oil or gas in your well?

WESTERN RESOURCE ASSOCIATES, INC

P.O. BOX 50370 RENO, NEVADA, 89513

GEOLOGIC WELL LOG

OPERATING COMPANY **Balcron Oil Company**

WELL NAME Bacon Flat Federal No. 23-17 FIELD Bacon Flat

LOCATION 2200' FSL & 1500' FWL COUNTY Nye

NE1/4, SE1/4 Section 17; T.7 N., R.57 E. STATE Nevada

DATE SPUDDED 7/25/92 DATE COMPLETED 8/13/92

ELEVATION : KB 4734.5' DF GL 4725'

TOTAL DEPTH 5240' PBTD STATUS Well completed from 5164'-5240' Initial production 1,000 barrels/day.

CASING RECORD Surface casing 9 5/8" set at 608'; production casing $2^{7}/_{8}$" tubing, completed from 5164'-5240'.

GEOLOGIST Kathleen Benedetto REMARKS Twisted off bit @ 5157'. No sample, retrieved fish drilled ahead to 5172', bit dropped 6"-12", lost circulation, assumed void in carbonates. Ran 1st DST, dolomite cuttings retrieved from material caked around DST tool. contained live oil yielding immediate bright yellow cut. Drilled ahead to 5220' w/increasing % dolomite in cuttings & increasing oil show. Logs: Dual Induction 608'-5201'; Sonic 608'-5194'; Dipmeter 3200-5200'

TESTING AND COMPLETION SUMMARY DST No. 1 5155'-5188': Tool plugged - first show.

DST No. 2 5190'-5220'; tool plugged. Cleaned and swabbed hole, ran production casing, flow test recovered 500 barrels of oil in 2 hrs. 10 min.

Scale 2" = 100 feet

LEGEND

LITHOLOGICAL SYMBOLS

- Valley Fill/Conglomerate
- Volcanics
- Clay, Volcanic Source
- Dolomite
- Fractures/Voids

POROSITY & SHOW SYMBOLS

- x Poor, xx Fair, xxx Good — Interparticle Porosity
- v Poor, vv Fair, vvv Good — Vug & Fracture Porosity
- Poor, Fair, Good — Oil Show

OPERATIONAL SYMBOLS

- DST
- Flow Test

WELL HISTORY AND DRILLING RATE (minutes/foot, 0–5–10)	DEPTH AND GRAPHIC LOG	POROSITY AND SHOWS	LITHOLOGIC DESCRIPTION	CORES AND TESTS

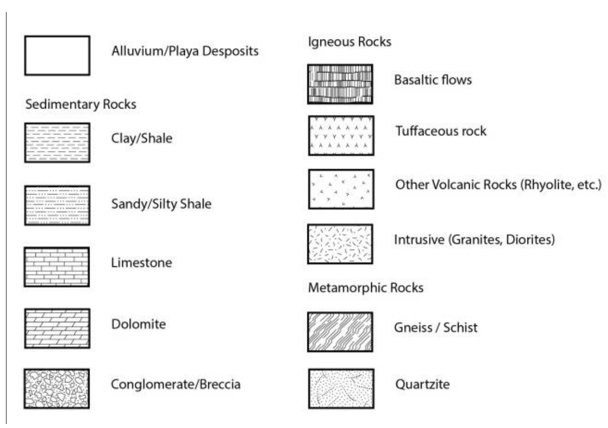
Depth	Porosity and Shows	Lithologic Description	Cores and Tests
Surface–4000'		NOTE: Cuttings logged from 4000' to 5220'. Mike Buckley, Columbine Logging, logged 5220'-5240' TD.	
4000'		0'-5030'(?): Valley fill conglomerate; predominantly Paleozoic carbonates, dolomite & limestone. 5-30%(+) volcanic tuff and ash fragments. Tuff fragments include both lithic and moderately welded crystal tuff. Most volcanic fragments swell and disintegrate in water. Dipyramidal quartz (or sanidine) and biotite books from the crystal tuff are found throughout the cuttings.	
4100'		Some metamorphic fragments and quartz & calcite vein material make up a small fraction of the valley fill.	
4160'		Slight increase in metamorphics.	
4280'		Slight increase in volcanics.	
4320'		Decrease in metamorphic fragments.	
4360'		Slight increase in volcanics.	
4420'		Slight increase in volcanics.	
4470'		Some fragments of pink tuff.	
4530'		15%-20% volcanics	
4550'		5%-8% volcanics	
4650'		15%-20% volcanics	
4700'		Trace bluegreen mineral CuOx or chlorite; some gossany fragments, granular carbonate w/pyrite, some garnet.	
4870'		20% volcanics	
4950'		20%-25% volcanics	
5000'		20% volcanic fragments	
5020'		5030': Valley fill/volcanic tuff contact? Volcanics are light green (chlorite) pyritic tuff, bentonitic(?).	
5070'		Light green clay-volcanic, 25% Volcanics	
5100'		70% volcanic tuff — NOTE: First oil show in dolomite fragments washed from material packed around DST tool. Fast streaming immediate cut w/bright yellow-green fluorescence	
5130'		60% volcanic tuff	
5140'		50% volcanic tuff	
5150'	No Sample	5157': Tuff/Dolomite contact. 50% volcanic tuff, light brown dolomite, charcoal grey limestone, misc. qtz. & biotite grains.	DST ①; Flow Test
5170'	No Sample	Bit dropped, 5"-12" lost circ.	
5180'	xx v v	Mostly lost circ. materials & v. small light colored frags.	
5190'	xx v v	90% dolomite; 25% fluorescence.	
5200'	xx v v	25%-35% fluorescence	DST ②
5210'	xx v v	Rainbow oil stain; 50% fluorescence	
5220'	xx v v	Increases to 70% fluorescence	
5230'	xx vvv	NOTE: 5180'-5190'; mostly lost circulation materials & very fine grained light colored rock fragments, vol. tuff & dolomite. 5190' to TD; 90%(+) dolomite.	
5240 TD			

You drill another well nearby at Lat: 38 28’ 37” & Lon: -115 33’ 52”, but decide to drill deeper this time. You find the following deposit at the depths (from surface) listed below by the top of the units:

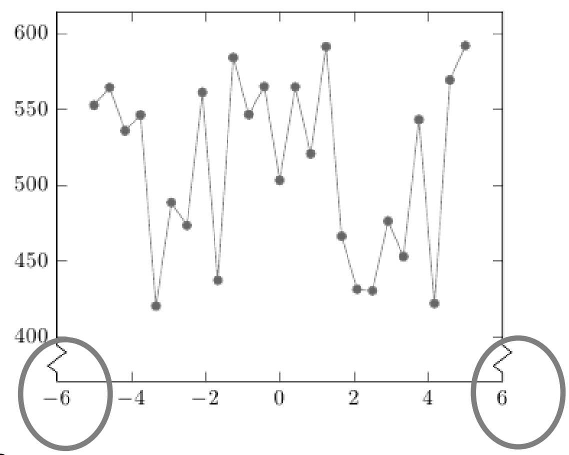
Note: Often well logs are not complete for the first few thousand feet of the well in order to save time and costs during drilling. Reported here are only the depths of interest for exploration of oil and gas resources. In this case assume the depth of alluvium and bedrock contact was not included, but the basin fill alluvium was present in upper portions of the well.

Rock Type *(from Part I)*	**Type Locality**	**Depth (ft)**
	7	?
	3	6690
	2	6888
	1	7110
	5	7322
Total Depth of Well		*7977*

Make a well log of your findings (use the attached graph paper). Geologists have some conventions for symbolizing map units, but flexibility is allowed, such as the addition of fossil illustrations (if found) or intermixed symbols for mixed/interbedded units, **please symbolize units as necessary** using previous well log as an example. *You may need to create a way to shorten large portions of the well log that include units that are not important to oil exploration (near surface). See example below of how this is done for the simple graph on the right and symbolize any missing data on your well log.*



Example of graph that contains missing data:



Do the units make sense, have you seen these before?

Why do you think some units are missing that you mapped in the field?

What is the minimum thickness of possible producing units?

Name: Date:

Grid is not perfectly square

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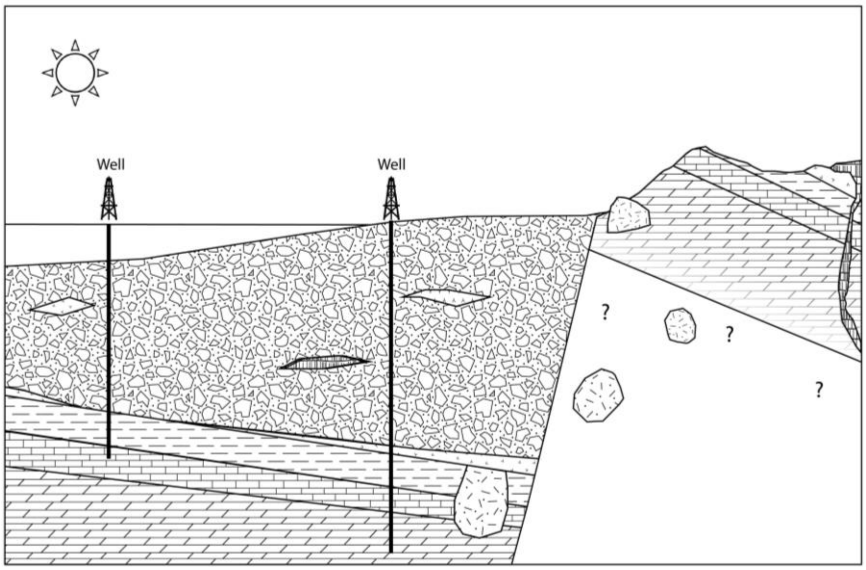
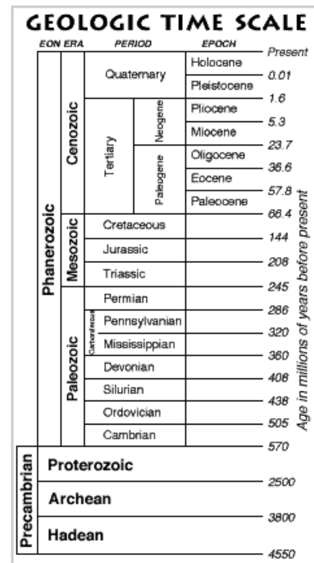
Park IV. Relative Ages and Data Interpretations. Create Map Legend.

Using the information from your wells, a well site geologist makes the following preliminary geologic interpretation and draws up a cross section that summarizes the geologic deposits in this area. Rocks types are symbolized using the same convention as used in the well logs.





We can now better understand the ages of the units using the information we have collected.

We know that during much of the Paleozoic Era Nevada was experiencing orogenies, or mountain building events, and was often covered by a inland seas. Later during the Mesozoic, Nevada experienced stretching and thinning that led to volcanism and faulting which created the Basin and Range as we know it today, this faulting has continued into the present day. We can see all of these features in the cross section above, and in fact, mapping and exploration like this is how we know these events happed in the past.

Which rock types were deposited during the times of inland seas?

Which rock types were deposited during the times of volcanism?

By combining information from your mapping, well logs and geologic interpretations, we are ready to create the legend on your geologic map. Legends list youngest deposits at the top, and then older units progressively down, with the oldest on the bottom.

Unit abbreviations generally start with the time Period (capital letter) and then a clue to rock type (lower case), for example Dc for a Devonian carbonate (limestone/dolomite) unit. **There may be a few different ways to interpret and name these units since you don't have exact ages, but make an educated hypothesis of appropriate ages (Periods) within the appropriate Eras described above and give them a unit abbreviation using this convention.** The cross-section and general geologic history should give you clues to relative ages of deposits.

Build your map legend using this information. Your legend should list the rock type with the abbreviation in the appropriate order to the right of each rectangle. Color in each rectangle with the same colors that correspond with the rocks and colors you chose for the map.

Map Legend

- Rock Sample Locations
- Well Locations

Fault - Hatches on down-thrown side

☐ ______________________________

☐ ______________________________

☐ ______________________________

☐ ______________________________

☐ ______________________________

☐ ______________________________

☐ ______________________________

☐ ______________________________

Your geologic map is now complete with the legend, notice that other important parts of the map, like the scale bar and north arrow, have been included for you on the map you completed in Part II.

Part V. Cost of Drilling, Generated Revenue and Profits

Drilling costs in Nevada can be especially high due to the rural location of wells, which means you have to import not only equipment and materials, but employees to the site. At this location costs were as high as $175,000 a day and each well took 30 days to complete. The BLM bond was $10,000 and annual lease of the land is $50000. How much money did you spend on drilling in the first year of each well so far?

In areas where the permeability of the rock and the pressure differences between surface and downhole allow the reservoir to flow with minimal pumping you were able to recover 102,000 barrels of oil per year at each location. At today's current price of $66.99 $/barrel how much money (in dollars) were you able to produce from these wells in the first year?

Did you make enough money in the first year of production to cover the costs of drilling? How much? How much was this per well? Do you have enough money left over to drill another well? What are your options for making money to drill the next well?

Typically a well will produce the most oil during their first years of production. Although you will make money over the life of the well, you may need to increase your initial profit margin for the next wells you drill if you are going to get serious investors to continue operations. Keep in mind, you still don't know the extent of your resource but it's likely that it could be larger than your test area! **What are some ways you can increase the production of your well?**

Part VI: Hydraulic Fracturing. We will now attempt to use hydraulic fracturing methods to produce more oil from the wells you drilled. By holding open fractures in the rock you may be able to produce more oil and gas from the formation.

See attached .pdf instructions on how to complete the Hydraulic Fracturing activity.

Answer the following questions:

After fracking you are able to increase your production by 500% per year, but the cost of hydraulic fracturing increased overall costs by $2,000,000. How much revenue are the wells able to produce per year? How much has your profit margin increased?

What are some way you can further increase your investment with future exploration and production of this oil field? Think about permitting costs required for land disturbance issues (cost per well pad) and new technologies.

In this exercise you were lucky to find a source rock (the shale) and a reservoir rock (the limestone) in a structure that was able to trap your resource. In some states large amounts of oil and gas remained trapped in the source rock without the permeability to flow, and with no reservoir rock or trap. **What options do you have for producing from these types of 'tight' resources?**

Drilling for Energy in Nevada

Geothermal

Oil & Gas

Nevada Division of Minerals
minerals.nv.gov
Carson City (775) 684-7040
Las Vegas (702) 486-4343

Activity

Version Two

Intermediate Template

Includes: one rock to identify from hand sample, three rocks to identify from descriptions only, four type-localities to plot on map, and well log that already has depths and tops drawn in.

Rocks required by this activity have been provided in Minerals/Rock Kit during the Minerals Education Teachers Workshop hosted by the Nevada Mining Association and the Nevada Division of Minerals

Contact ndom@minerals.nv.gov or see https://www.nevadamining.org/mineral-education-workshops/ for more information.

Activity Created by C.M. Brailo, Nevada Division of Minerals *2018-07-09*

Drilling for Energy in Nevada
Classroom Activity

Created for the Nevada Mineral Education Workshop
by C.M.Brailo – Nevada Division of Minerals, 2018

Purpose/Introduction: Nevada is a state plentiful in energy resources. These resources include geothermal, solar and wind energy fields that exist throughout the state. Nevada also has oil and gas resources and has a robust history of successful oil wells. During the 1980s one oil field in southeastern Nevada included some of the highest producing wells in the country for its time, although now technologies and reserves in other states, such as North Dakota and Texas, have greatly surpassed Nevada's production. Nevada has produced over 53,000,000 barrels of oil throughout its history. The state currently hovers around 27th out of 30 oil and gas producing states in terms of barrels of oil and gas produced, with the majority of the wells located in rural parts of the state. Many states rely on hydraulic fracturing technology to successfully produce oil and gas from their wells. In contrast, Nevada has very little hydraulically fractured wells, three fields in total ever utilized the technology, and no horizontally drilled wells. However, should new wells choose to use the technology here the state has passed some of the strictest hydraulic fracturing laws in the nation, with key emphasis on well construction that ensures the protection of fresh water aquifers that exist at relatively shallow depths as compared to the oil and gas targets. This activity will highlight the process of exploration and extraction of oil with a Nevada-specific case example and hands-on activity.

For more information on the history of oil production in Nevada and currently Nevada oil and gas production statistics see the Nevada Bureau of Mines and Geology (http://www.nbmg.unr.edu/Oil&Gas/HistoricalSummary.html) and the Nevada Division of Minerals (http://minerals.nv.gov/Programs/OG/OG/) websites.

Materials:

- Rock Identification Kit
- Nevada-specific Rock Samples
- Outcrop Map
- Colored Pencils
- Rulers
- Knox Gelatin
- Syringe and Tubing
- Plaster of Paris
- Empty Water Bottles

Activity with Instructions:

Part I. Rock Identification: you are hiking through the foothills in eastern Nevada. You find an interesting rock in one of the washes. Use the following chart to identify your rock.

Rock Location	Color	Grain Size	Texture: Layered or Massive?	Unique Properties	Igneous, Sedimentary, Metamorphic?	Rock Name
1: Lat: 38° 32' 22" Lon:-115°26' 06"						

You become curious if there are other rocks like this around in the area. You proceed to identify rocks from different places around the valley (collecting and documenting the locations of the samples you collect). The following chart includes descriptions of rocks you found at type-localities (places where you found the best specimens and good examples of the deposit). **Identify your rocks by filling in table below.**

Rock Location	Color	Grain Size	Texture: Layered or Massive?	Unique Properties	Igneous, Sedimentary, Metamorphic?	Rock Name
2: Lat: 38° 28' 51" Lon: -115° 24' 07"	Grey to brown	Very fine grained	Layered with very fine beds	Smooth, rare small fossils found, greasy feel	Sedimentary	
3: Lat: 38° 36' 43" Lon: -115° 23' 45"	Light tan, white and some light pink	Fine	Massive	Felsic minerals	Volcanic - Extrusive	
4: Lat: 38° 32' 54" Lon: -115° 21' 40"	Dark brown to black	No visible grains	Massive with rare bubbly texture	Signs of flow, rare gas bubbles and small olivine crystals	Volcanic	
5: Lat: 38° 25' 33" Lon: -115° 28' 15"	Grey to tan	Fine	Massive	Reacts with acid only when scratched	Sedimentary	Dolomite
6: Lat: 38° 23' 24." Lon: -115° 34' 01"	White with some black clasts	Med to coarse grained	Massive	Large crystals of quartz and biotite but no plagioclase	Volcanic - Intrusive	Granite
7: Lat: 38° 32' 10" Lon: -115° 31' 23"	Mixed clasts, grey, brown, tan and black	Varied sands to cobbles and boulder s	Clasts range from massive to layered	Faulted – large range of clasts – has many drainages and hummocky terrain	Unconsolidated Sediments	Alluvial Sediments/ Fan (see photo below)
8: Lat: 38° 29' 50" Lon: -115° 37' 55"	Light tan to white	Fine	Layered	Smooth surface in center of basin, with evaporates	Unconsolidated Sediments	Playa

Faulting in alluvial sediments at Railroad Valley (type locality 8 above)

Are there units that could be profitable for oil, natural gas or mineral exploration?

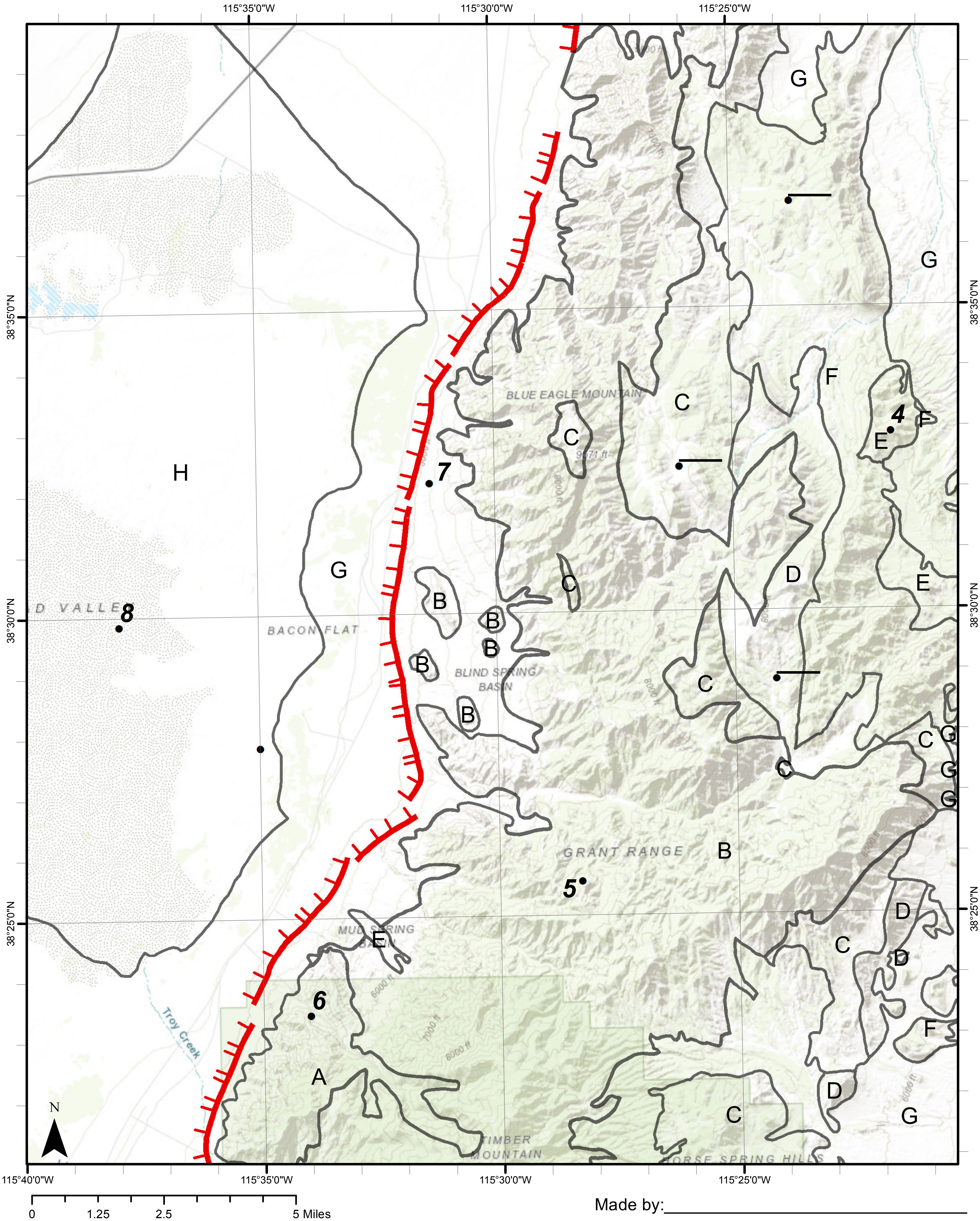
Part II. CREATE A GEOLOGIC MAP

Further mapping (boots on the ground!) leads to the discovery of geologic contacts, or boundaries, for each of these deposits. You even find map out a major fault in the area (see photo above). The attached map depicts these boundries. The geologic rock units are labeled by the letters A-I on the map.

On the provided map, locate and label where the type locality rocks (best representive of the geologic unit) were found that you identified in the table in Part I.

Pick a color to represent the rock type for each of your geologic units and color in the boundaries for each rock type to make a professional looking geologic map. You will eventually need a legend for your map, but we will build it after we have more information about the rock units.

Railroad Valley Geologic Map



Made by:________________________________

Is it possible that the outcrops you have mapped could be located deeper in the basin where they may have been heated enough to produce oil or gas? What evidence do you have to support your conclusion? *Hint: Think about structural evolution of the NV basin and features you have found during mapping.*

How might you find out more about these rocks at depth?

Part III. Well Logs

You decide to drill some exploration holes and see what lies in the basin! You do the land research and find out the area you are interested in is owned by BLM. You find investors that believe in your resource potential, you obtain a lease from the BLM, and obtain BLM and State permits to drill. This also requires that a bond be put in place to ensure proper plugging and reclamation of the well is completed after drilling.

You drill the well at: Lat: 38° 27' 49" Lon: -115° 34' 59". This location is plotted on the map and the well log on the attached page shows your results.

Did you find similar rock units that you identified during the geologic mapping stage?

Are there any signs of oil or gas in your well?

WRA **WESTERN RESOURCE ASSOCIATES, INC**
P.O. BOX 50370 RENO, NEVADA, 89513

GEOLOGIC WELL LOG

OPERATING COMPANY **Balcron Oil Company**

WELL NAME Bacon Flat Federal No. 23-17 FIELD Bacon Flat

LOCATION 2200' FSL & 1500' FWL COUNTY Nye

NE1/4, SE1/4 Section 17; T.7 N., R.57 E. STATE Nevada

DATE SPUDDED 7/25/92 DATE COMPLETED 8/13/92

ELEVATION: KB 4734.5' DF ______ GL 4725'

TOTAL DEPTH 5240' PBTD ______ STATUS Well completed from 5164'-5240' Initial production 1,000 barrels/day.

CASING RECORD Surface casing 9 5/8" set at 608'; production casing 2 7/8" tubing, completed from 5164'-5240'.

GEOLOGIST Kathleen Benedetto REMARKS Twisted off bit @ 5157'. No sample, retrieved fish drilled ahead to 5172', bit dropped 5"-12", lost circulation, assumed void in carbonates. Ran 1st DST, dolomite cuttings retrieved from material caked around DST tool, contained live oil yielding immediate bright yellow cut. Drilled ahead to 5220' w/increasing % dolomite in cuttings & increasing oil show. Logs: Dual Induction 608'-5201'; Sonic 608'-5194'; Dipmeter 3200-5200'

TESTING AND COMPLETION SUMMARY DST No. 1 5155'-5188': Tool plugged - first show.
DST No. 2 5190'-5220': tool plugged. Cleaned and swabbed hole, ran production casing, flow test recovered 500 barrels of oil in 2 hrs. 10 min.

Scale 2" = 100 feet

LEGEND

LITHOLOGICAL SYMBOLS	POROSITY & SHOW SYMBOLS
Valley Fill/Conglomerate	Interparticle Porosity: x Poor, xx Fair, xxx Good
Volcanics	Vug & Fracture Porosity: v Poor, vv Fair, vvv Good
Clay, Volcanic Source	Oil Show: Poor, Fair, Good
Dolomite	
Fractures/Voids	

OPERATIONAL SYMBOLS: DST; Flow Test

Depth	Porosity and Shows	Lithologic Description	Cores and Tests
Surface to 4000'		NOTE: Cuttings logged from 4000' to 5220'. Mike Buckley, Columbine Logging, logged 5220'-5240' TD.	
4000'–4100'		0'-5030'(?): Valley fill conglomerate; predominantly Paleozoic carbonates, dolomite & limestone. 5-30%(+) volcanic tuff and ash fragments. Tuff fragments include both lithic and moderately welded crystal tuff. Most volcanic fragments swell and disintegrate in water. Dipyramidal quartz (or sanidine) and biotite books from the crystal tuff are found throughout the cuttings.	
4100'–4200'		Some metamorphic fragments and quartz & calcite vein material make up a small fraction of the valley fill.	
		Slight increase in metamorphics.	
4200'–4300'		Slight increase in volcanics.	
4300'–4400'		Decrease in metamorphic fragments.	
		Slight increase in volcanics.	
4400'–4500'		Slight increase in volcanics.	
		Some fragments of pink tuff.	
4500'–4600'		15%-20% volcanics	
		5%-8% volcanics	
4600'–4700'		15%-20% volcanics	
4700'–4800'		Trace bluegreen mineral CuOx or chlorite; some gossany fragments, granular carbonate w/pyrite, some garnet.	
4800'–4900'		20% volcanics	
4900'–5000'		20%-25% volcanics	
5000'–5100'		20% volcanic fragments	
		5030': Valley fill/volcanic tuff contact? Volcanics are light green (chlorite) pyritic tuff, bentonitic(?)	
		Light green clay-volcanic, 25% Volcanics	
5100'–5240'		70% volcanic tuff; NOTE: First oil show in dolomite fragments washed from material packed around DST tool. Fast streaming immediate cut w/bright yellow-green fluorescence.	
		60% volcanic tuff	
		50% volcanic tuff	
	No Sample	5157' Tuff/Dolomite contact. 50% volcanic tuff, light brown dolomite, charcoal grey limestone, misc. qtz. & biotite grains.	DST ①
	No Sample	Bit dropped, 5"-12" lost circ.	
	xx vv	Mostly lost circ. materials & v. small light colored frags.	
	xx vv	90% dolomite; 25% fluorescence.	
	xx vv	25%-35% fluorescence	DST ②
	xx vv	Rainbow oil stain; 50% fluorescence	Flow Test
	xx vv	Increases to 70% fluorescence	
	xx vvv	NOTE: 5180'-5190'; mostly lost circulation materials & very fine grained light colored rock fragments, vol. tuff & dolomite. 5190' to TD: 90%(+) dolomite.	

You drill another well nearby at Lat: 38 28' 37" & Lon: -115 33' 52", but decide to drill deeper this time. You find the following deposit at the elevation (sea level) and depths (from surface) listed below by the top of the units:

Note: Often well logs are not complete for the first few thousand feet of the well in order to save time and costs during drilling. Reported here are only the depths of interest for exploration of oil and gas resources. In this case assume the depth of alluvium and bedrock contact was not included, but the basin fill alluvium was present in upper portions of the well.

Rock Type *(from Part I)*	**Type Locality**	**Depth (ft)**
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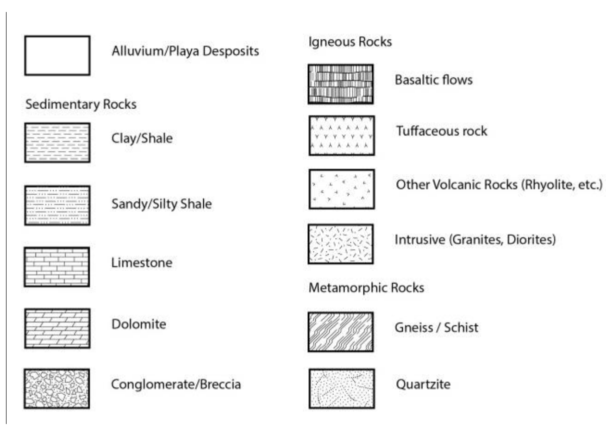
Total Depth of Well		*7977*

Make a well log of your findings (use the attached graph paper). Geologists have some conventions for symbolizing map units, but flexibility is allowed, such as the addition of fossil illustrations (if found) or intermixed symbols for mixed/interbedded units, **please symbolize units as necessary** using previous well log as an example**.** You may need to create a way to shorten large portions of the well log that include units that are not important to oil exploration (near surface). See example below of how this is done for the simple graph on the right and symbolize any missing data on your well log.



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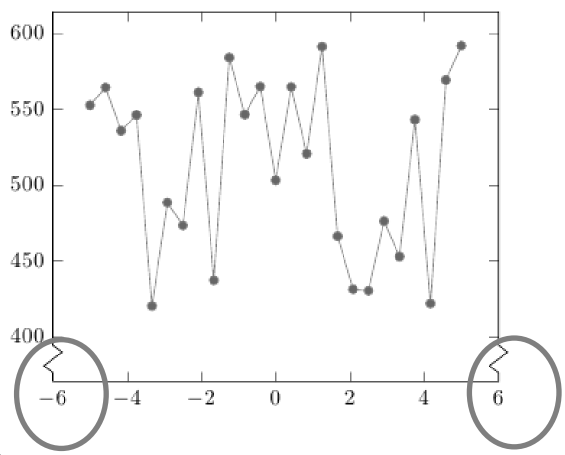


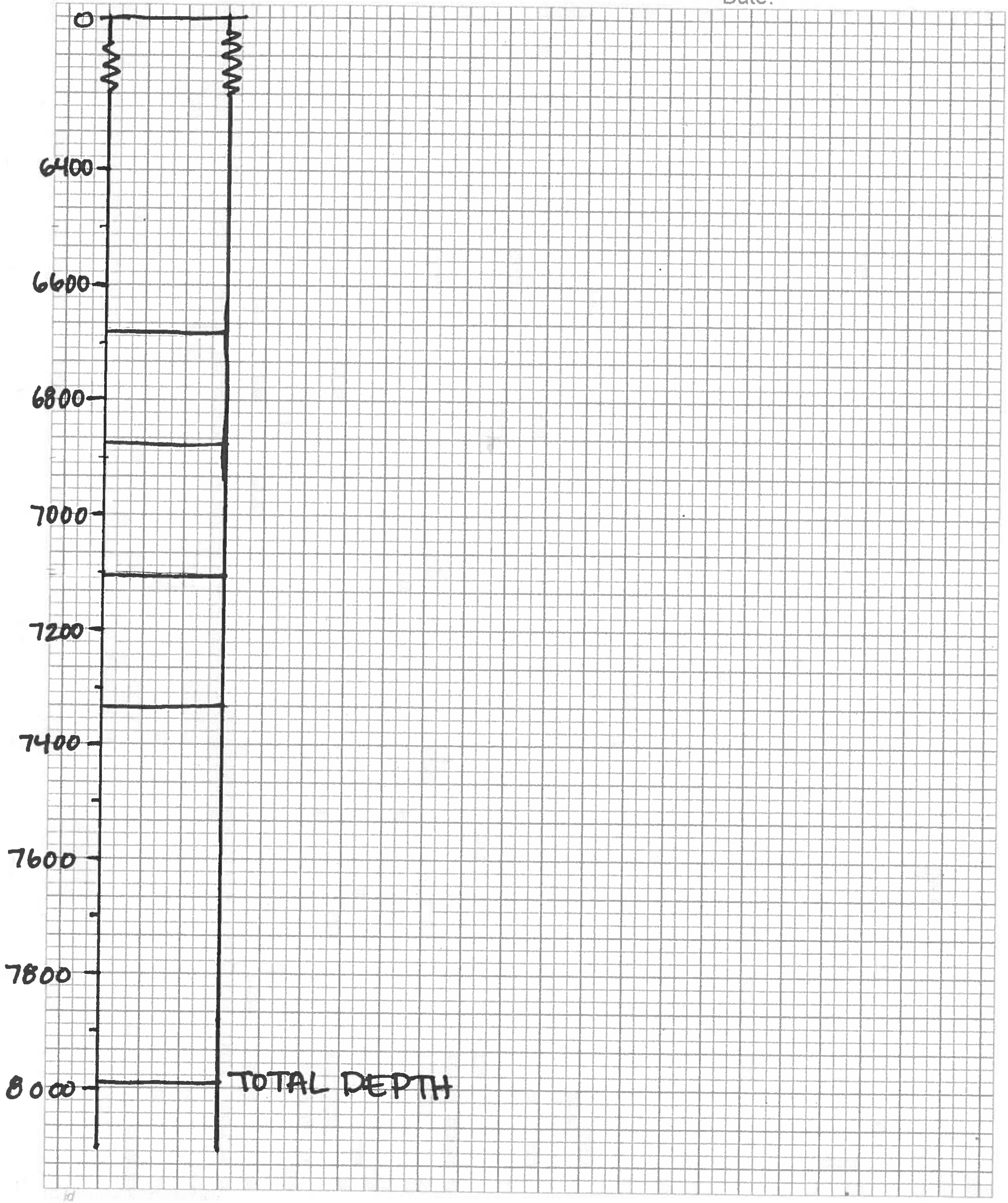
Do the units make sense, have you seen these before?

Why do you think some units are missing that you mapped in the field?

What is the minimum thickness of possible producing units?

Name:

Date:



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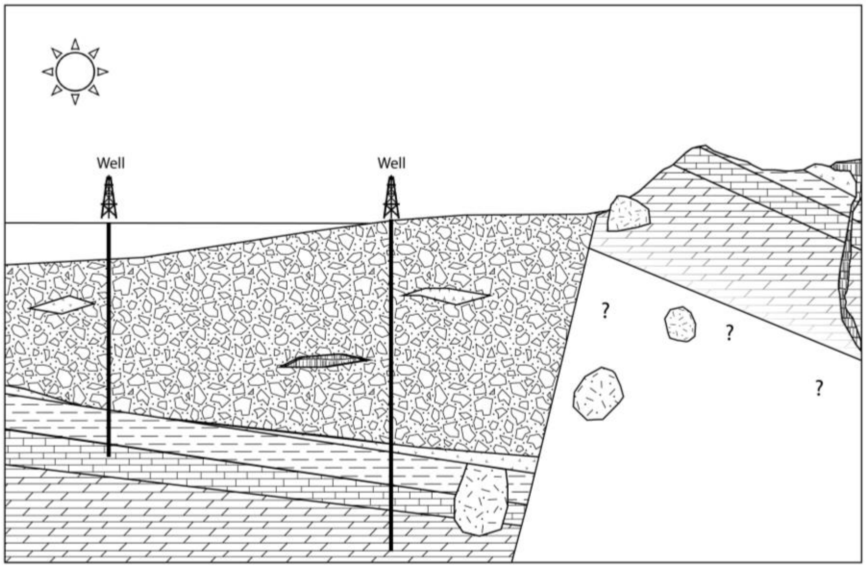

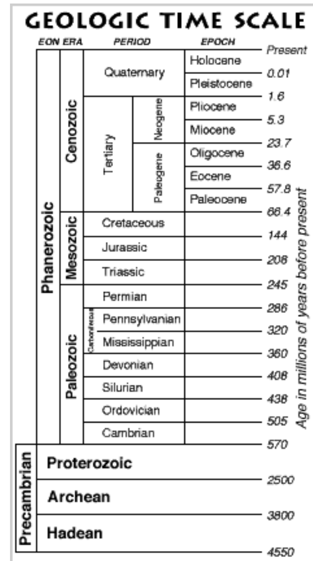

We can now better understand the ages of the units using the information we have collected.

We know that during much of the Paleozoic Era Nevada was experiencing orogenies, or mountain building events, and was often covered by a inland seas. Later during the Mesozoic, Nevada experienced stretching and thinning that led to volcanism and faulting which created the Basin and Range as we know it today, this faulting has continued into the present day. We can see all of these features in the cross section above, and in fact, mapping and exploration like this is how we know these events happed in the past.

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By combining information from your mapping, well logs and geologic interpretations, we are ready to create the legend on your geologic map. Legends list youngest deposits at the top, and then older units progressively down, with the oldest on the bottom.

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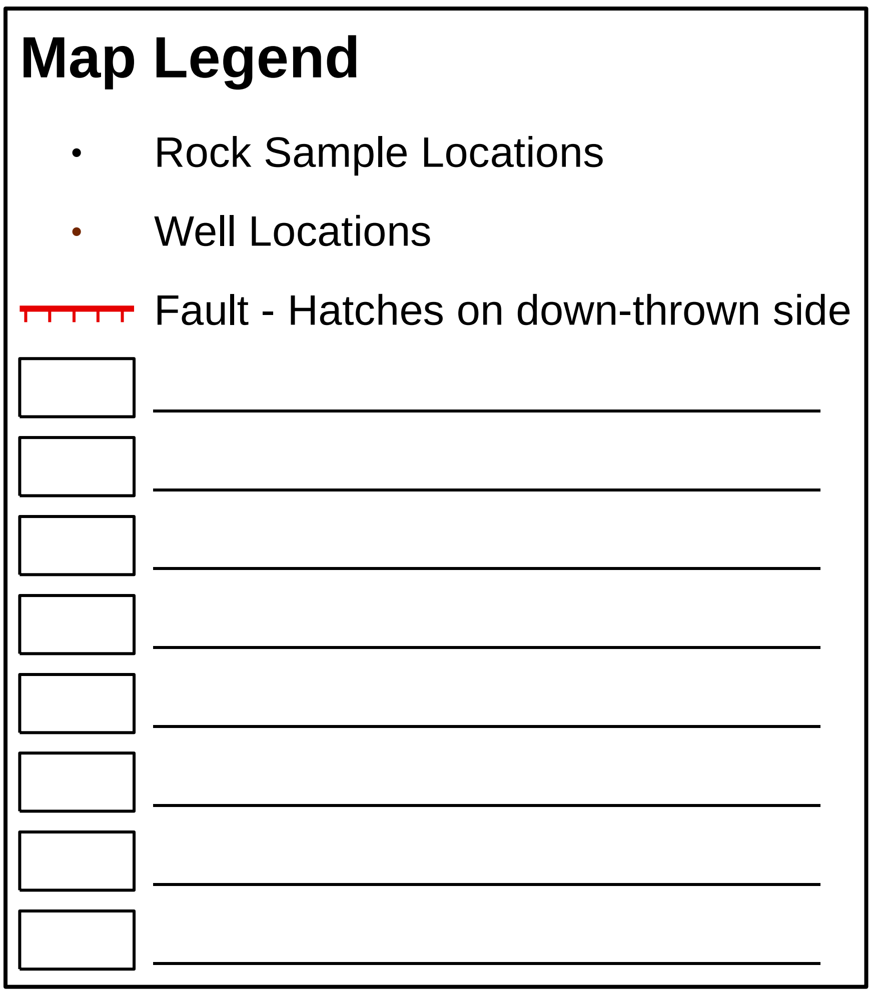

Your geologic map is now complete with the legend, notice that other important parts of the map, like the scale bar and north arrow, have been included for you on the map you completed in Part II.

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Drilling costs in Nevada can be especially high due to the rural location of wells, which means you have to import not only equipment and materials, but employees to the site. At this location costs were as high as $175,000 a day and each well took 30 days to complete. The BLM bond was $10,000 and annual lease of the land is $50000. How much money did you spend on drilling in the first year of each well so far?

In areas where the permeability of the rock and the pressure differences between surface and downhole allow the reservoir to flow with minimal pumping you were able to recover 102,000 barrels of oil per year at each location. At today's current price of $66.99 $/barrel how much money (in dollars) were you able to produce from these wells in the first year?

Did you make enough money in the first year of production to cover the costs of drilling? How much? How much was this per well? Do you have enough money left over to drill another well? What are your options for making money to drill the next well?

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After fracking you are able to increase your production by 500% per year, but the cost of hydraulic fracturing increased overall costs by $2,000,000. How much revenue are the wells able to produce per year? How much has your profit margin increased?

What are some way you can further increase your investment with future exploration and production of this oil field? Think about permitting costs required for land disturbance issues (cost per well pad) and new technologies.

In this exercise you were lucky to find a source rock (the shale) and a reservoir rock (the limestone) in a structure that was able to trap your resource. In some states large amounts of oil and gas remained trapped in the source rock without the permeability to flow, and with no reservoir rock or trap. **What options do you have for producing from these types of 'tight' resources?**

Drilling for Energy in Nevada

Geothermal

Oil & Gas

Nevada Division of Minerals

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Activity

Version Three

Key – Completed rock identifications, descriptions, maps and well logs

Rocks required by this activity have been provided in Minerals/Rock Kit during the Minerals Education Teachers Workshop hosted by the Nevada Mining Association and the Nevada Division of Minerals

Contact ndom@minerals.nv.gov or see https://www.nevadamining.org/mineral-education-workshops/ for more information.

Activity Created by C.M. Brailo, Nevada Division of Minerals 2018-07-09

Drilling for Energy in Nevada
Classroom Activity

Created for the Nevada Mineral Education Workshop
by C.M.Brailo – Nevada Division of Minerals, 2018

Purpose/Introduction: Nevada is a state plentiful in energy resources. These resources include geothermal, solar and wind energy fields that exist throughout the state. Nevada also has oil and gas resources and has a robust history of successful oil wells. During the 1980s one oil field in southeastern Nevada included some of the highest producing wells in the country for its time, although now technologies and reserves in other states, such as North Dakota and Texas, have greatly surpassed Nevada's production. Nevada has produced over 53,000,000 barrels of oil throughout its history. The state currently hovers around 27th out of 30 oil and gas producing states in terms of barrels of oil and gas produced, with the majority of the wells located in rural parts of the state. Many states rely on hydraulic fracturing technology to successfully produce oil and gas from their wells. In contrast, Nevada has very little hydraulically fractured wells, three fields in total ever utilized the technology, and no horizontally drilled wells. However, should new wells choose to use the technology here the state has passed some of the strictest hydraulic fracturing laws in the nation, with key emphasis on well construction that ensures the protection of fresh water aquifers that exist at relatively shallow depths as compared to the oil and gas targets. This activity will highlight the process of exploration and extraction of oil with a Nevada-specific case example and hands-on activity.

For more information on the history of oil production in Nevada and currently Nevada oil and gas production statistics see the Nevada Bureau of Mines and Geology (http://www.nbmg.unr.edu/Oil&Gas/HistoricalSummary.html) and the Nevada Division of Minerals (http://minerals.nv.gov/Programs/OG/OG/) websites.

Materials:

- Rock Identification Kit
- Nevada-specific Rock Samples
- Outcrop Map
- Colored Pencils
- Rulers
- Knox Gelatin
- Syringe and Tubing
- Plaster of Paris
- Empty Water Bottles

Activity with Instructions:

Part I. Rock Identification: you are hiking through the foothills in eastern Nevada. You find an interesting rock in one of the washes. Use the following chart to identify your rock.

Rock Location	Color	Grain Size	Texture: Layered or Massive?	Unique Properties	Igneous, Sedimentary, Metamorphic?	Rock Name
1: Lat: 38° 32' 22" Lon:-115°26' 06"	**Grey**	**Fine to medium**	**Massive**	**Contains fossils**	**Sedimentary**	**Limestone**

You become curious if there are other rocks like this around in the area. You proceed to identify rocks from different places around the valley (collecting and documenting the locations of the samples you collect). The following chart includes descriptions of rocks you found at type-localities (places where you found the best specimens and good examples of the deposit). **Identify your rocks by filling in table below.**

Rock Location	Color	Grain Size	Texture: Layered or Massive?	Unique Properties	Igneous, Sedimentary, Metamorphic?	Rock Name
2: Lat: 38° 28' 51" Lon: -115° 24' 07"	Grey to brown	Very fine grained	Layered with very fine beds	Smooth, rare small fossils found, greasy feel	Sedimentary	**Shale**
3: Lat: 38° 36' 43" Lon: -115° 23' 45"	Light tan, white and some light pink	Fine	Massive	Felsic minerals	Volcanic - Extrusive	**Rhyolite**
4: Lat: 38° 32' 54" Lon: -115° 21' 40"	Dark brown to black	No visible grains	Massive with rare bubbly texture	Signs of flow, rare gas bubbles and small olivine crystals	Volcanic	**Basalt**
5: Lat: 38° 25' 33" Lon: -115° 28' 15"	Grey to tan	Fine	Massive	Reacts with acid only when scratched	Sedimentary	Dolomite
6: Lat: 38° 23' 24." Lon: -115° 34' 01"	White with some black clasts	Med to coarse grained	Massive	Large crystals of quartz and biotite but no plagioclase	Volcanic - Intrusive	Granite
7: Lat: 38° 32' 10" Lon: -115° 31' 23"	Mixed clasts, grey, brown, tan and black	Varied sands to cobbles and boulders	Clasts range from massive to layered	Faulted – large range of clasts – has many drainages and hummocky terrain	Unconsolidated Sediments	Alluvial Sediments/Fan (see photo below)
8: Lat: 38° 29' 50" Lon: -115° 37' 55"	Light tan to white	Fine	Layered	Smooth surface in center of basin, with evaporates	Unconsolidated Sediments	Playa

Faulting in alluvial sediments at Railroad Valley (type locality 8 above)

Are there units that could be profitable for oil, natural gas or mineral exploration?

There are fossiliferous limestones, dolomites and shales! Could potentially have a reservoirs and a source, maybe even a trapped reserve!

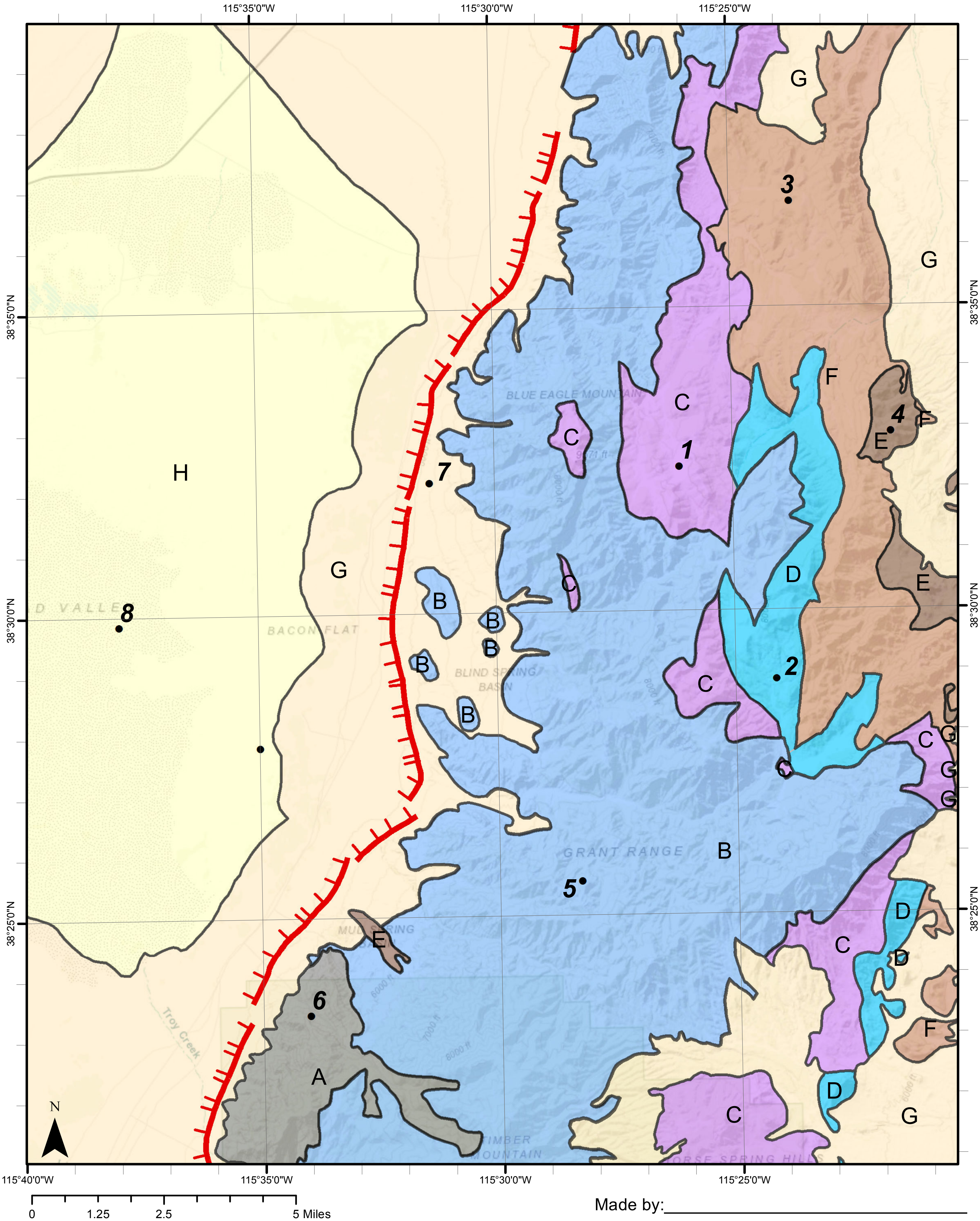
Part II. CREATE A GEOLOGIC MAP

Further mapping (boots on the ground!) leads to the discovery of geologic contacts, or boundaries, for each of these deposits. You even find map out a major fault in the area (see photo above). The attached map depicts these boundries. The geologic rock units are labeled by the letters A-I on the map.

On the provided map, locate and label where the type locality rocks (best representive of the geologic unit) were found that you identified in the table in Part I.

Pick a color to represent the rock type for each of your geologic units and color in the boundaries for each rock type to make a professional looking geologic map. You will eventually need a legend for your map, but we will build it after we have more information about the rock units.

Railroad Valley Geologic Map



Made by:______________________________

Is it possible that the outcrops you have mapped could be located deeper in the basin where they may have been heated enough to produce oil or gas? What evidence do you have to support your conclusion? *Hint: Think about structural evolution of the NV basin and features you have found during mapping.*

Yes! The faults I mapped had a down-thrown side to the west, meaning the basin has gone down relative to the eastern mountain range! They are probably down there! We don't know yet if they have been heated to the right temperatures to create oil and gas.

How might you find out more about these rocks at depth?

The shales could be a trap for oil. The limestones could be either a reservoir or a trap depending on porosity of the particular unit; we hope it's a reservoir. We could drill and see if these have the needed structure at depth.

Part III. Well Logs

You decide to drill some exploration holes and see what lies in the basin! You do the land research and find out the area you are interested in is owned by BLM. You find investors that believe in your resource potential, you obtain a lease from the BLM, and obtain BLM and State permits to drill. This also requires that a bond be put in place to ensure proper plugging and reclamation of the well is completed after drilling.

You drill the well at: Lat: 38° 27' 49" Lon: -115° 34' 59". This location is plotted on the map and the well log on the attached page shows your results.

Do you find similar rock units in the well logs that you identified during the geologic mapping stage?

Yes, there is the alluvium unit, which has volcanic fragments in it. Below the alluvium there is the volcanic tuff which is similar to the rhyolite we saw, and then there is dolomite and limestone below that.

Are there any signs of oil or gas in your well?

Yes! Oil shows occurred just before 5200'.

WRA **WESTERN RESOURCE ASSOCIATES, INC**

P.O. BOX 50370 RENO, NEVADA, 89513

GEOLOGIC WELL LOG

OPERATING COMPANY **Balcron Oil Company**

WELL NAME Bacon Flat Federal No. 23-17 FIELD Bacon Flat

LOCATION 2200' FSL & 1500' FWL COUNTY Nye

NE1/4, SE1/4 Section 17; T.7 N., R.57 E. STATE Nevada

DATE SPUDDED 7/25/92 DATE COMPLETED 8/13/92

ELEVATION : KB 4734.5' DF ______ GL 4725'

TOTAL DEPTH 5240' PBTD ______ STATUS Well completed from 5164'-5240' Initial production 1,000 barrels/day.

CASING RECORD Surface casing 9 5/8" set at 608'; production casing $2^{7}/_{8}$" tubing, completed from 5164'-5240'.

GEOLOGIST Kathleen Benedetto REMARKS Twisted off bit @ 5157'. No sample, retrieved fish drilled ahead to 5172', bit dropped 6"-12", lost circulation, assumed void in carbonates. Ran 1st DST, dolomite cuttings retrieved from material caked around DST tool, contained live oil yielding immediate bright yellow cut. Drilled ahead to 5220' w/increasing % dolomite in cuttings & increasing oil show. Logs: Dual Induction 608'-5201'; Sonic 608'-5194'; Dipmeter 3200-5200'

TESTING AND COMPLETION SUMMARY DST No. 1 5155'-5188': Tool plugged - first show. DST No. 2 5190'-5220'; tool plugged. Cleaned and swabbed hole, ran production casing, flow test recovered 500 barrels of oil in 2 hrs. 10 min.

Scale 2" = 100 feet

LEGEND

LITHOLOGICAL SYMBOLS

- Valley Fill/Conglomerate
- Volcanics
- Clay, Volcanic Source
- Dolomite
- Fractures/Voids

POROSITY & SHOW SYMBOLS

- Interparticle Porosity: x Poor, xx Fair, xxx Good
- Vug & Fracture Porosity: v Poor, vv Fair, vvv Good
- Oil Show: Poor, Fair, Good

OPERATIONAL SYMBOLS

- (2) DST
- Flow Test

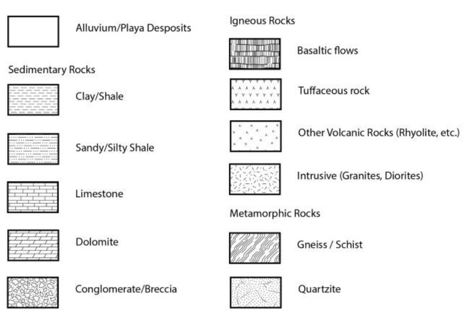
WELL HISTORY AND DRILLING RATE (minutes/foot, 0–5–10)	DEPTH AND GRAPHIC LOG	POROSITY AND SHOWS	LITHOLOGIC DESCRIPTION	CORES AND TESTS
	Surface to 4000' valley fill.		NOTE: Cuttings logged from 4000' to 5220'. Mike Buckley, Columbine Logging, logged 5220'-5240' TD.	
4000' 8/2/92	4000'		0'-5030'(?): Valley fill conglomerate; predominantly Paleozoic carbonates, dolomite & limestone. 5-30%(+) volcanic tuff and ash fragments. Tuff fragments include both lithic and moderately welded crystal tuff. Most volcanic fragments swell and disintegrate in water. Dipyramidal quartz (or sanidine) and biotite books from the crystal tuff are found throughout the cuttings.	
	4100'		Some metamorphic fragments and quartz & calcite vein material make up a small fraction of the valley fill.	
	50'		Slight increase in metamorphics.	
GEOLOGRAPH OUT	4200'			
GEOLOGRAPH OUT	50'		Slight increase in volcanics.	
4294' 8/3/92	4300'		Decrease in metamorphic fragments.	
	50'		Slight increase in volcanics.	
	4400'		Slight increase in volcanics.	
	50'		Some fragments of pink tuff.	
	4500'		15%-20% volcanics	
4548' 8/4/92	50'		5%-8% volcanics	
	4600'			
	50'		15%-20% volcanics	
	4700'		Trace bluegreen mineral CuOx or chlorite; some gossany fragments, granular carbonate w/pyrite, some garnet.	
4783' 8/5/92	50'			
4847' 8/6/92 4:28 PM TOH for new bit; 2:00 AM Drill ahead	4800' / 50'		20% volcanics	
	4900' / 50'		20%-25% volcanics	
	5000'		20% volcanic fragments	
			5030': Valley fill/volcanic tuff contact? Volcanics are light green (chlorite) pyritic tuff, bentonitic(?).	
5062' 8/7/92	50'		Light green clay-volcanic, 25% Volcanics	
	5100'		70% volcanic tuff. NOTE: First oil show in dolomite fragments washed from material packed around DST tool. Fast ~~streaming immediate cut w/bright~~ yellow-green fluorescence	
			~~60% volcanic tuff~~	
	50'		50% volcanic tuff	
5157' 8/8/92 Twisted off 8th collar from bottom 11:18 PM		No Sample	5157': Tuff/Dolomite contact. 50% volcanic tuff, light brown dolomite, charcoal grey limestone, misc. qtz. & biotite grains.	(1)
		No Sample	Bit dropped, 5"-12" lost circ.	
5182' 8/9/92 Lost circ.		xx vv	Mostly lost circ. materials & v. small light colored frags.	
		xx vv	90% dolomite; 25% fluorescence.	
	5200'	xx vv	25%-35% fluorescence	(2)
		xx vv	Rainbow oil stain; 50% fluorescence	
		xx vv	Increases to 70% fluorescence	
		xx vvv	NOTE: 5180'-5190'; mostly lost circulation materials & very fine grained light colored rock fragments, vol. tuff & dolomite. 5190' to TD: 90%(+) dolomite.	
	5240 TD			

You drill another well nearby at Lat: 38 28' 37" & Lon: -115 33' 52", but decide to drill deeper this time. You find the following deposit at the depths (from surface) listed below by the top of the units:

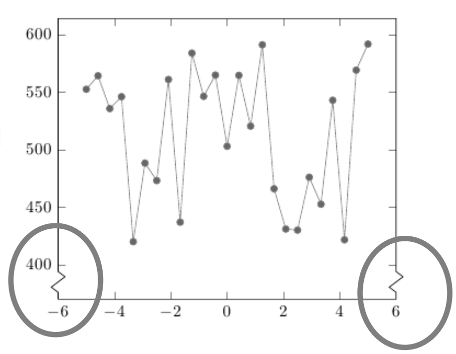
Note: Often well logs are not complete for the first few thousand feet of the well in order to save time and costs during drilling. Reported here are only the depths of interest for exploration of oil and gas resources. In this case assume the depth of alluvium and bedrock contact was not included, but the basin fill alluvium was present in upper portions of the well.

Rock Type *(from Part I)*	**Type Locality**	**Depth (ft)**
Alluvium (Qal)	7	?
Rhyolite (Ts)	3	6690
Shale (Ms)	2	6888
Limestone (MDl)	1	7110
Dolomite (Dd)	5	7322
Total Depth of Well		*7977*

Make a well log of your findings (use the attached graph paper). Geologists have some conventions for symbolizing map units, but flexibility is allowed, such as the addition of fossil illustrations (if found) or intermixed symbols for mixed/interbedded units, **please symbolize units as necessary** using previous well log as an example. *You may need to create a way to shorten large portions of the well log that include units that are not important to oil exploration (near surface). See example below of how this is done for the simple graph on the right and symbolize any missing data on your well log.*



Example of graph that contains missing data:

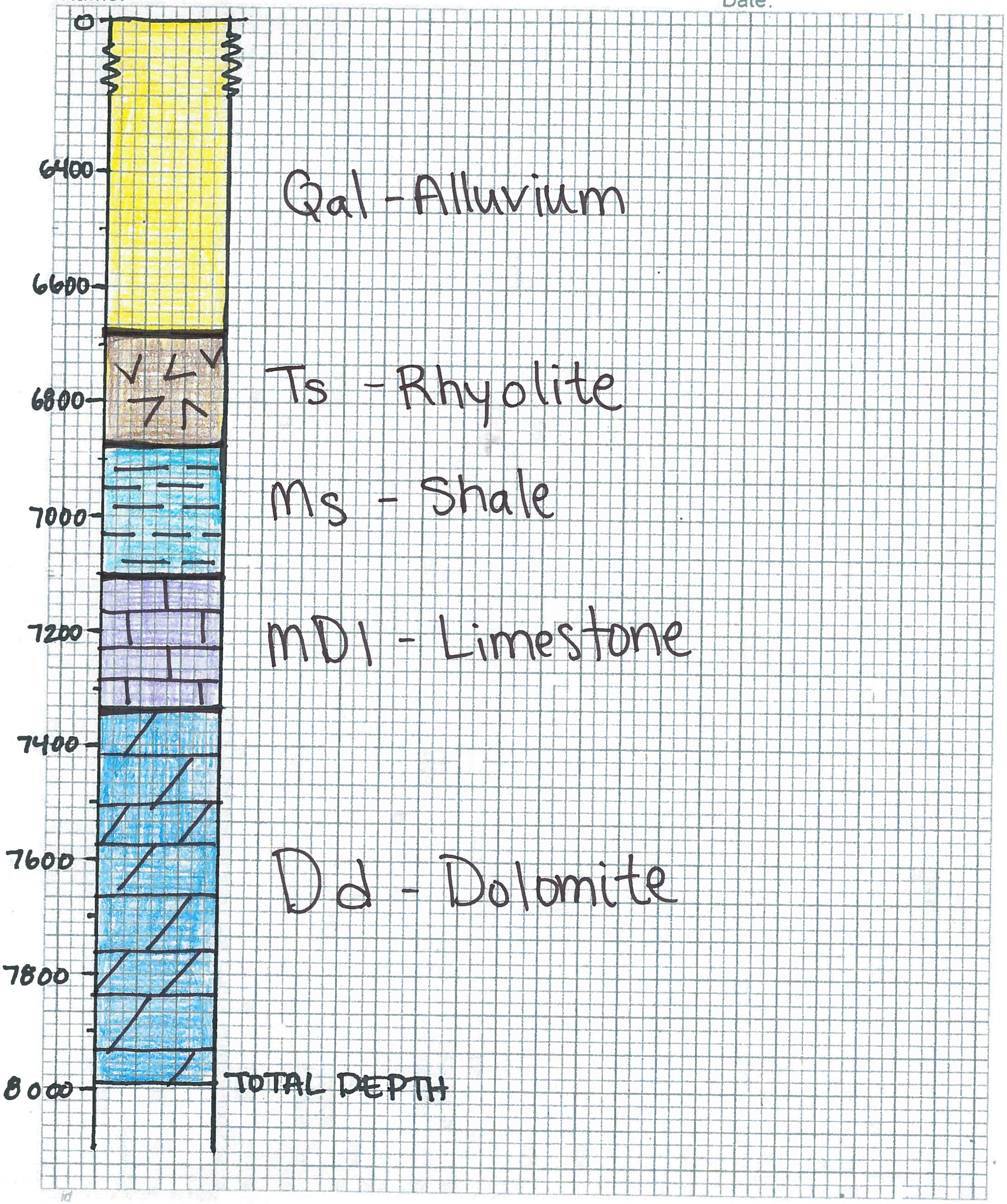


Do the units make sense, have you seen these before? Yes the rock units resembled those that I found in outcrop during my mapping; although a few were missing that I did not see in the well log.

Why do you think some units are missing that you mapped in the field? They were likely surficial and/or localized deposits that post-dated the down-dropping of the basin or did not extend to the well location from the outcrop.

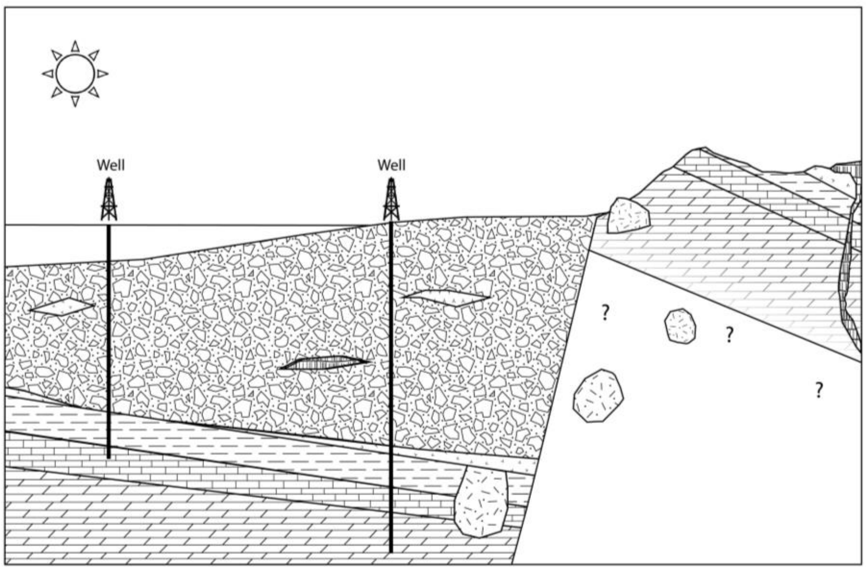
What is the minimum thickness of possible producing units? The shales, dolomites and limestones could be oil producers. They are at least 7977'-6888' = 1089' thick.

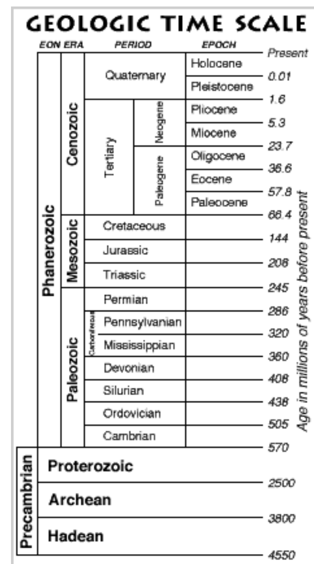
Name: Date:


0
6400
6600
6800
7000
7200
7400
7600
7800
8000
Qal - Alluvium
Ts - Rhyolite
Ms - Shale
MDl - Limestone
Dd - Dolomite
TOTAL DEPTH

Park IV. Relative Ages and Data Interpretations. Create Map Legend.

Using the information from your wells, a well site geologist makes the following preliminary geologic interpretation and draws up a cross section that summarizes the geologic deposits in this area. Rocks types are symbolized using the same convention as used in the well logs.





We can now better understand the ages of the units using the information we have collected.

We know that during much of the Paleozoic Era Nevada was experiencing orogenies, or mountain building events, and was often covered by a inland seas. Later during the Mesozoic, Nevada experienced stretching and thinning that led to volcanism and faulting which created the Basin and Range as we know it today, this faulting has continued into the present day. We can see all of these features in the cross section above, and in fact, mapping and exploration like this is how we know these events happed in the past.

Which rock types were deposited during the times of inland seas?

Dolomites (Dd), Limestones (MDl) and shales (Ms)

Which rock types were deposited during the times of volcanism?

Rhyolite (Ts), Granitic Intrusions (Jg), Basalt flows (Qb)

By combining information from your mapping, well logs and geologic interpretations, we are ready to create the legend on your geologic map. Legends list youngest deposits at the top, and then older units progressively down, with the oldest on the bottom.

Unit abbreviations generally start with the time Period (capital letter) and then a clue to rock type (lower case), for example Dc for a Devonian carbonate (limestone/dolomite) unit. **There may be a few different ways to interpret and name these units since you don't have exact ages, but make an educated hypothesis of appropriate ages (Periods) within the appropriate Eras described above and give them a unit abbreviation using this convention.** The cross-section and general geologic history should give you clues to relative ages of deposits.

Build your map legend using this information. Your legend should list the rock type with the abbreviation in the appropriate order to the right of each rectangle. Color in each rectangle with the same colors that correspond with the rocks and colors you chose for the map.

Map Legend

- Rock Sample Locations
- Well Locations
- Fault - Hatches on down-thrown side
- Qpl - Playa/lake bed deposits (H8)
- Qal - Alluvium (G7)
- Qb - Basalt flows (E4)
- Ts - Rhyolites, Tuffs (F3)
- Jg - Granites, Diorites (A6)
- Ms - Shales (D2)
- MDl - Limestone (C1)
- Dd - Dolomite (B5)

Your geologic map is now complete, notice that the map's scale bar and north arrow have been included for you, which are important parts of any map.

Part V. Cost of Drilling, Generated Revenue and Profits

Drilling costs in Nevada can be especially high due to the rural location of wells, which means you have to import not only equipment and materials, but employees to the site. At this location costs were as high as $175,000 a day and each well took 30 days to complete. The BLM bond was $10,000 and annual lease of the land is $50000. How much money did you spend on drilling in the first year of each well so far?

$175,000 x 30 days = $5,250,000

($5,250,000 x 2 days) + $10,000 + $5,000= $10,505,000

In areas where the permeability of the rock and the pressure differences between surface and downhole allow the reservoir to flow with minimal pumping you were able to recover 102,000 barrels of oil per year at each location. At today's current price of $66.99 $/barrel how much money (in dollars) were you able to produce from these wells in the first year?

102,000 barrels x $66.99/barrel = $6,832,980

$6,832,980 x 2 = $13,665,960

Did you make enough money in the first year of production to cover the costs of drilling? How much? How much was this per well? Do you have enough money left over to drill another well? What are your options for making money to drill the next well?

Yes. $13,665,960 - $10,515,000 = $3,150,960 in profits, but not enough to drill another well. It took $5,250,000 to drill the last one, assuming you use the same lease and bond money you would be need $2,099,040 more investment money, or to wait until the wells produced enough to pay for more wells.

Typically a well will produce the most oil during their first years of production. Although you will make money over the life of the well, you may need to increase your initial profit margin for the next wells you drill if you are going to get serious investors to continue operations. Keep in mind, you still don't know the extent of your resource but it's likely that it could be larger than your test area! **What are some ways you can increase the production of your well?**

Use hydraulic fracturing methods to increase production!

Part VI: Hydraulic Fracturing. We will now attempt to use hydraulic fracturing methods to produce more oil from the wells you drilled. By holding open fractures in the rock you may be able to produce more oil and gas from the formation.

See attached .pdf instructions on how to complete the Hydraulic Fracturing activity.

Answer the following questions:

After fracking you are able to increase your production by 500% per year, but the cost of hydraulic fracturing increased overall costs by $2,000,000. How much revenue are the wells able to produce per year? How much has your profit margin increased?

Cost: $10,515,000+ ($2,000,00 x 2) = $14,515,000

Revenue: $13,665,960 x 5 = $68,329,800

Total Profit: $53,814,800 Can drill many wells!

What are some others ways you can further increase your investment with future exploration and production of this oil field? Think about permitting costs required for land disturbance issues (cost per well pad) and new technologies.

Drill more than one well per pad and use horizontal drilling to access full extent of reservoir.

In this exercise you were lucky to find a source rock (the shale) and a reservoir rock (the limestone) in a structure that was able to trap your resource. In some states large amounts of oil and gas remained trapped in the source rock without the permeability to flow, and with no reservoir rock or trap. **What options do you have for producing from these types of 'tight' resources?**

Hydraulic fracturing is the only way to produce from these resources!

Drilling for Energy in Nevada

Geothermal

Oil & Gas

Nevada Division of Minerals
minerals.nv.gov
Carson City (775) 684-7040
Las Vegas (702) 486-4343

Activity

Additional Pages/Alternative Activities

Customizable Maps/Logs/Rock Identifications

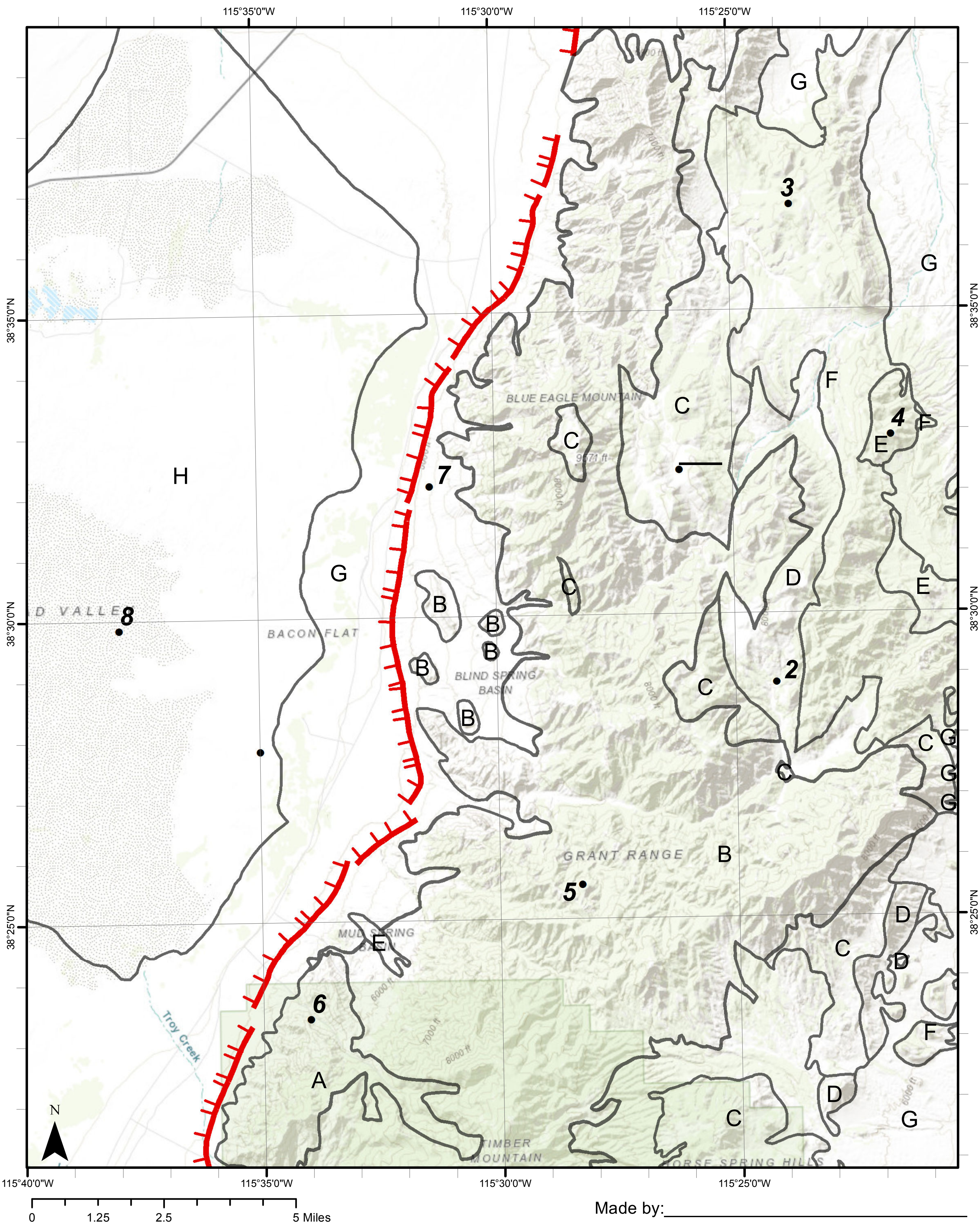
Varying Degree of Difficulty

Rocks required by this activity have been provided in Minerals/Rock Kit during the Minerals Education Teachers Workshop hosted by the Nevada Mining Association and the Nevada Division of Minerals

Contact ndom@minerals.nv.gov or see https://www.nevadamining.org/mineral-education-workshops/ for more information.

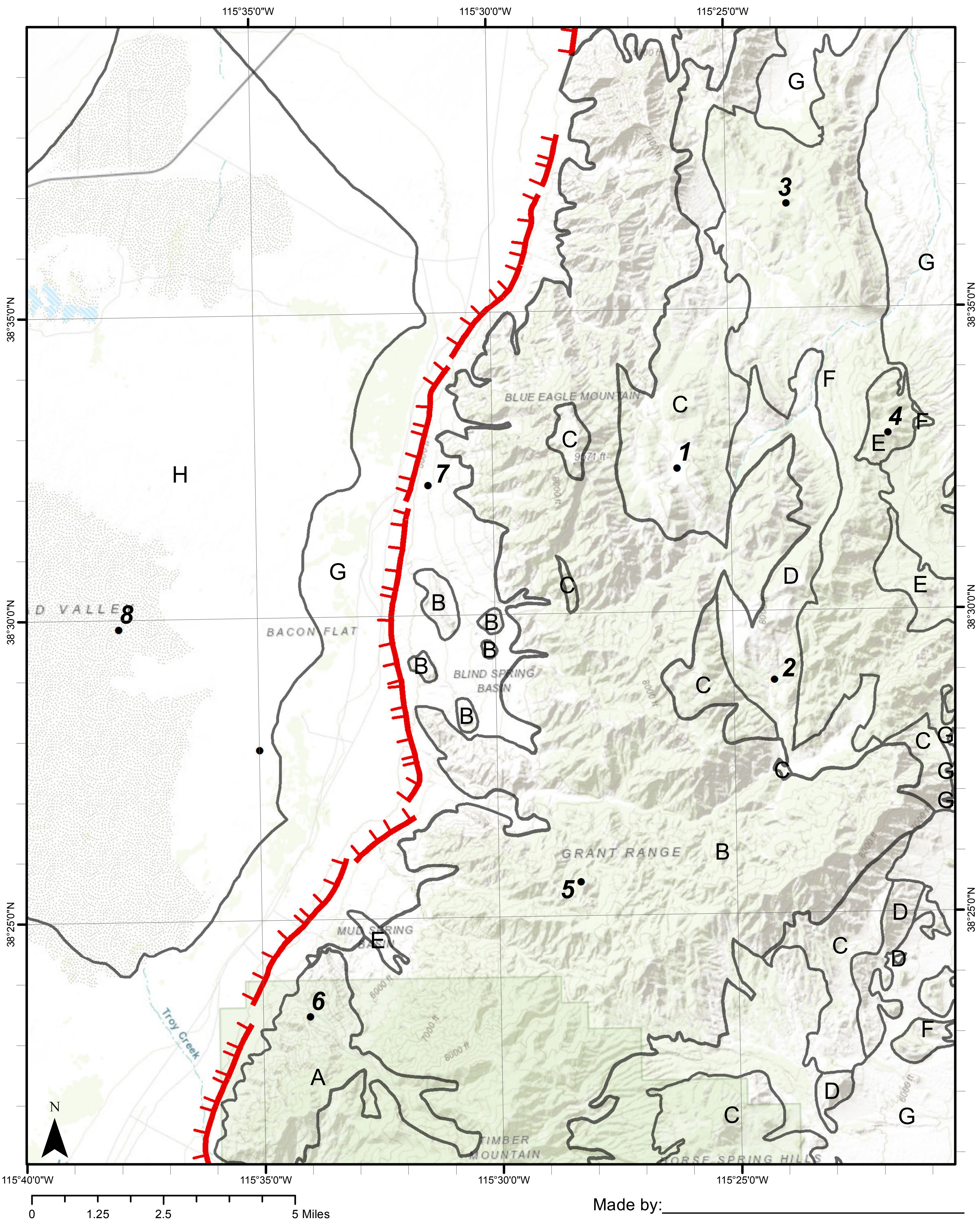
Activity Created by C.M. Brailo, Nevada Division of Minerals 2018-07-09

Railroad Valley Geologic Map



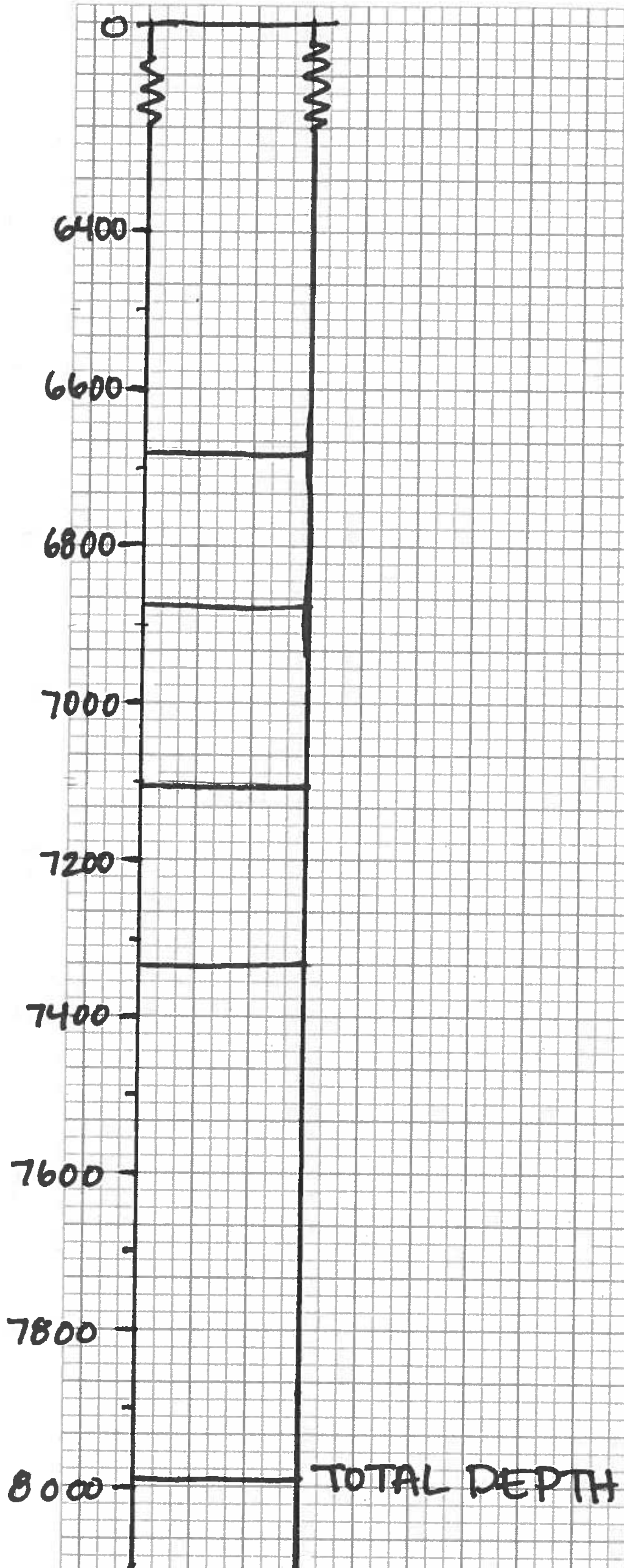
Made by:________________________________

Railroad Valley Geologic Map



Made by:________________________________

Name: Date:



Name:

Date:

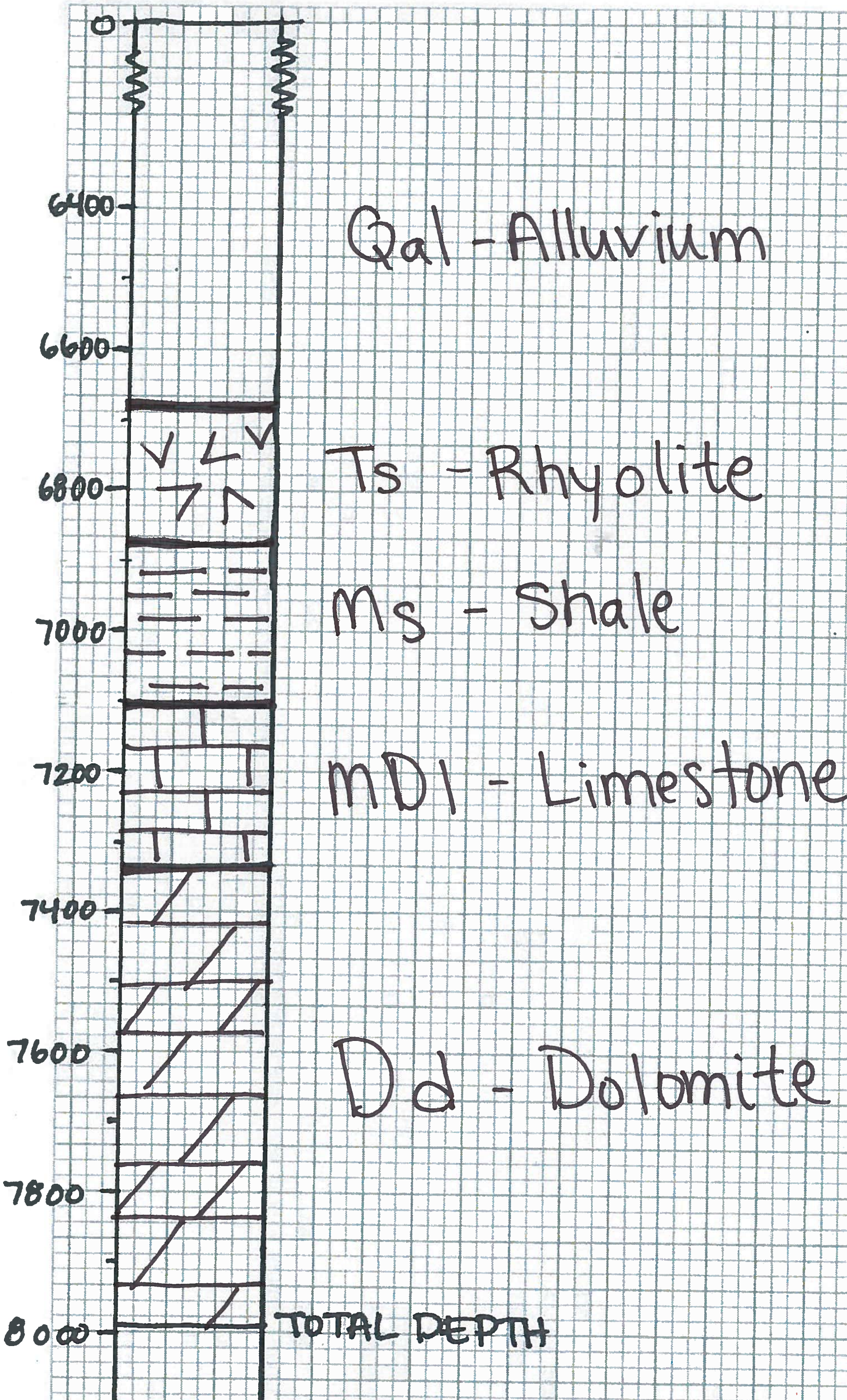
Ts - Rhyolite

Ms - Shale

mDl - Limestone

Dd - Dolomite

Name: Date:


0
6400
6600
6800
7000
7200
7400
7600
7800
8000
TOTAL DEPTH
Qal - Alluvium
Ts - Rhyolite
Ms - Shale
MDl - Limestone
Dd - Dolomite

FORMATION TOPS

Formation	Sample Tops KB Depth & Datum		Log Tops KB Depth & Datum		Structural Comp
Miocene Basalt	Not	Present			
Erosional Tert. Volcanics			6690	(-1935)	-477
Chainman Shale	6910	(-2155)	6888	(-2133)	-55
Joana Limestone	7104	(-2349)	7110	(-2355)	+319
Fault Zone	7254	(-2499)	7255	(-2500)	-
Antelope Valley Limestone (Pogonip)	7309	(-2554)	7322	(-2567)	-

NOTE: Identification of formations was based on sample examination, lithology comparisons of other wells in the area, electrical log evaluations and microfossil age dating performed by Terry Hutter of TH Geological Services and Gerald Waanders of Waanders Palynology Consulting. The palynology reports are located beginning on page 9 of this report. The well used for structural comparison is the Shell Oil Co., Eagle Springs Unit #54-4 located in the SW NE Sec. 4-T7N-R57E, 3400' to the northwest.

Drilling for Energy in Nevada

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Hydraulic Fracturing Activity

From other sources – Compiled as supplemental material

Activity Created by C.M. Brailo, Nevada Division of Minerals *2018-07-09*

AirWaterGas

NSF Sustainability Research Network

Make a Fracking Model Activity

Introduction

Students will design a model to demonstrate how hydraulic fracturing aids in extracting oil and gas from shale deposits thousands of feet beneath the earth's surface.

Credits

Activity developed by UCAR AirWaterGas Teachers-in-Residence Shelly Grandell, Tori Hellman, and Rebecca Bradford.

This activity is modified from the NEED Project Fracturing With Gelatin Activity, found in the Wonders of Oil and Gas Unit.

Grade level: 6-12

Time Required

Class Time: 1 block period ~100 minutes or two 50-minute class periods

Learning Goal

Students will understand that horizontal drilling allows for more surface area of host rocks to be fracked after designing a model that demonstrates hydraulic fracturing methods.

Lesson Format (Content): Hands-on activity

Standards (*Next Generation Science Standards***)**

- ***MS ESS3.A*** *Natural Resources: Humans depend on Earth's land, ocean, atmosphere and biosphere for different resources, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.*
- ***HS-ESS3-1*** *Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. ESS3.A*
- ***HS-ESS3-2*** *Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. ESS3.A, ETS1.B*
- ***HS-ESS3-4*** *Evaluate or refine a technological solution that reduces impacts of human activities on natural systems ETS1.B, ESS3.C*

Materials for groups of three/class of 30

- Gelatin 40 packets, Knox gelatin works well
- Several 20 oz, empty plastic bottles, rinsed (one per group of students)
- Fracking fluid medium. Plaster of Paris works well (good representation of fracking fluid because it is granular and the grains represent the sand (proppant) in the fracking fluid).

- Veterinary catheter tubes, size 10-14 french
- Syringe that compliments catheter tube
- Large straw that catheter tube will thread through

Preparation

1. Collect empty PLASTIC water/soda bottles well before lab (have students each bring one in a few days before).
2. Make the gelatin the night before (use 1:4 ratio for more stable gelatin), and pour into the plastic bottles. Cool the gelatin in a refrigerator overnight.
3. In class, before students begin, mix plaster. Make the plaster right before you plan on using it, as plaster hardens quickly.

Introduction
Show students a picture of a stratigraphic column that contains a deep, tight, oil and gas bearing shale. Ask students to come up with ideas as to how they might access this deposit. Tell them that they may only make a 10-12 inch hole on the ground surface to reach the deposit.

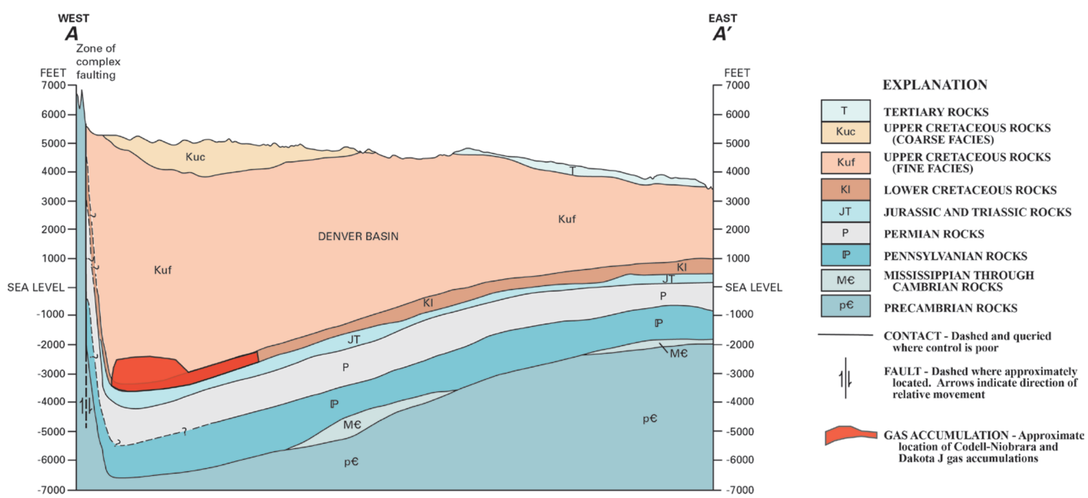


Image Credit: “Gas, Oil, and Water Production from Wattenberg Field in the Denver Basin, Colorado,” USGS Open-File Report 2011-1175.

Here is an example from the Denver area: Students would need to access the red bed.

Students will have a variety of answers. Lead the discussion into surface area by asking: How can we access the oil and gas bearing formation beyond the area reached with a vertical well? In oil and gas terminology, traditional drilling technology using vertical wells is called conventional oil and gas extraction.

Directions

Begin by passing out all materials to groups, and assembling the catheter/fracking apparatus.

Catheter Assembly:

- Attach open end of catheter tubing to a syringe
- Use paper clip or binder clip to pinch bottom of tube ABOVE holes, this will prevent fluid from leaking before injection (see Figure 1).

Procedure:

1. Take bottle with gelatin and lay on side
2. Insert the long, large straw to bore a hole about two thirds of the way through the gelatin to the bottom of the bottle. DO NOT GO ALL THE WAY TO BOTTOM! (see Figure 2)
3. Place thumb over end of straw, pull out slowly, and making sure to extract the gelatin core completely. This is the most difficult step. If there is not enough suction the gelatin core may not come out of the bottle completely, and the experiment won't work if the bore hole is blocked. Tip: You can apply suction with your mouth on the straw to extract the core as well.
4. After clearing the straw, reuse the straw from step 3, and place it into the bore hole, leaving one inch exposed at top of bottle (you will need to hold onto this during injection of fluid(see Figure 2)). This straw will serve as the well casing.
5. Now, using the fracking catheter assembly already constructed, fill the syringe full with the plaster mixture (ie. fracking fluid) while it is attached to the catheter tube, allowing the mixture to fill the tubing until both the syringe and tube are full.
6. Carefully put the plunger back into the syringe, without pushing the fracking fluid out.
7. Now, insert the catheter tubing into the straw, or well casing, until the tube extends past the borehole straw approximately 3 cm. into the gelatin (see Figure 3).
8. Using very firm, steady pressure, push the plunger to inject the plaster into the gelatin.
9. Observe the fracturing pattern of the gelatin.
10. Pull the tubing out of the gelatin carefully, trying not to disturb the fractures.
11. If desired, you can allow the gelatin and plaster to sit until the plaster hardens, and you can then extract the plaster cast of fracture pattern to make further observations by cutting the plastic bottle away and discarding the gelatin.

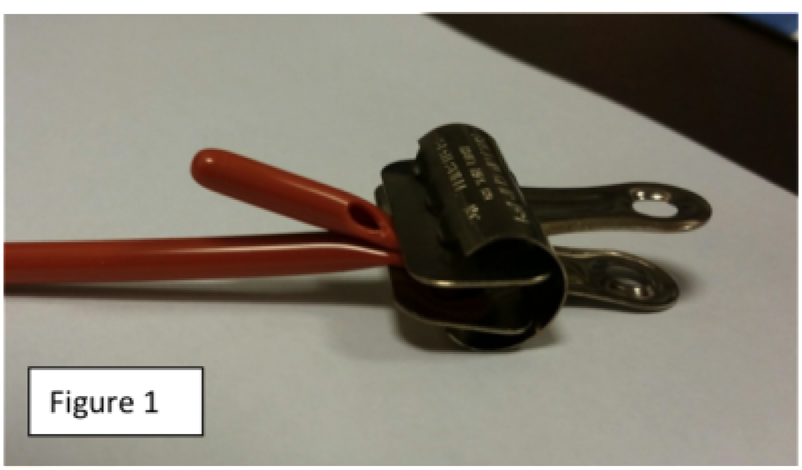
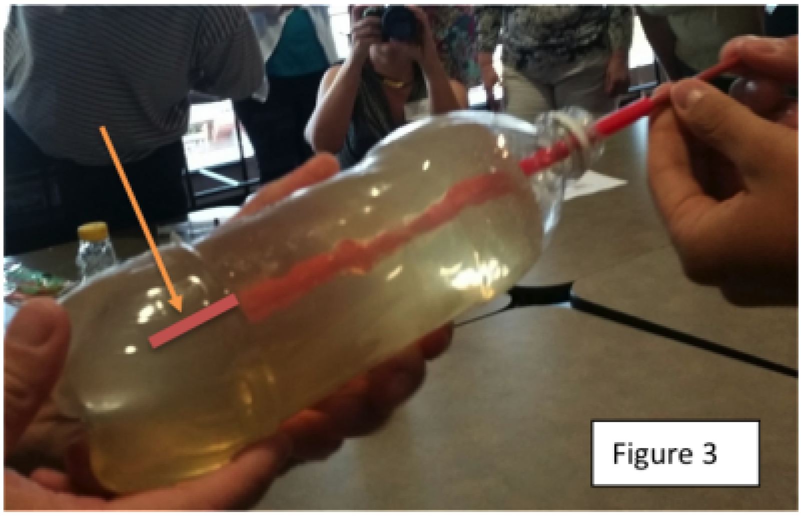


Figure 1



Assessment
Students should sketch and label their model and demonstrate an understanding of the relationship between the model and what a real hydraulic fracturing process would look like.

Assessment Questions:

1. Why did you have to apply pressure to fracking fluid to create fracture patterns?
2. How does this model represent hydraulic fracturing?
3. How does this model NOT represent hydraulic fracturing?
4. What improvements could be made to the model to make it more accurate and realistic?
5. How does the plaster simulate fracking fluid?
6. How does the plaster NOT simulate fracking fluid?
7. What does the casing straw represent? What kind of materials would you need to construct casing in the real world? Why?
8. Do you think if you changed the density of the fluid, would the fracture patterns be the same? Why?
9. What is the purpose of the proppant (grains) in the fluid?
10. Why do we hydraulically fracture wells?

Background information:
Access to oil and gas deposits in the U.S have become increasingly accessible through the advent of hydraulic fracturing. Hydraulic fracturing, known as fracking, is the process in which and oil and gas bearing host rock, such as shale, is injected with fracking fluid at high pressures to stimulate flow of hydrocarbons out of the well.

Fracking fluid is a mixture of water with sand and chemicals to aid in flow down the well. Wells used for hydraulic fracturingl can be vertically or horizontally drilled. Horizontal wells begin with an initial wellbore (the vertical component) then the hole is gradually turned about 90 degrees to be oriented horizontally within the oil and gas bearing formation. Horizontal wells can spread out for miles. Some single vertical wells can have multiple "fingers" spreading out in different directions inside the oil and gas bearing formation.
For a more detailed description of the fracking process, visit these sites:
http://www.fracfocus.org/hydraulic-fracturing-process
http://www.usgs.gov/hydraulic_fracturing/
http://www2.epa.gov/hydraulicfracturing

Extensions
Try using different fluids than Plaster of Paris, or vary the density of the Plaster of Paris.

Use activity as an inquiry project. Provide the students with all of the materials and have them develop a design to model hydraulic fracturing. Have the students defend why their model best represents hydraulic fracturing.

Alternate Procedure & Materials:
If you are unable to find catheter tubing, you can use two straws with different diameters, with one that fits inside the other. Follow the procedure below:

Straw Assembly:

- About 10 millimeters from one end of small straw, use a push pin to poke about ten holes 5 millimeters apart, with five holes on each side in a straight line.
- Use a small piece of duct tape to seal the perforated end of the small straw.
- Use duct tape to attach a syringe to the non-perforated end of the small straw and insure that no leaks are possible.
- Cut one large straw for the borehole/casing in half and set aside.
- Follow the above procedure starting on step 3.

Drilling for Energy in Nevada

Geothermal

Oil & Gas

Nevada Division of Minerals
minerals.nv.gov
Carson City (775) 684-7040
Las Vegas (702) 486-4343

Other Activities

From other sources – Compiled as supplemental material

2017-2018

Wonders of Oil and Natural Gas

Hands-on explorations and language arts activities that introduce students to the basic concepts of oil and natural gas formation, composition, exploration, production, and use.

Grade Level:

Elem Elementary

Subject Areas:

Science

Social Studies

Math

Language Arts

Technology

NEED

National Energy Education Development Project

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In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

Energy Data Used in NEED Materials

NEED believes in providing teachers and students with the most recently reported, available, and accurate energy data. Most statistics and data contained within this guide are derived from the U.S. Energy Information Administration. Data is compiled and updated annually where available. Where annual updates are not available, the most current, complete data year available at the time of updates is accessed and printed in NEED materials. To further research energy data, visit the EIA website at www.eia.gov.

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National Energy
Education Development

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www.NEED.org
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Wonders of Oil and Natural Gas

Oil and Natural Gas Kit

- 1 *Oil, Natural Gas, and Their Energy* Teacher/Student Guide
- 1 *Wonders of Oil and Natural Gas* Teacher/Student Guide
- 1 *Exploring Oil and Natural Gas* Teacher/Student Guide
- 5 Large metal slinkies
- 5 Small foam cups
- 5 Large foam cups
- 5 9oz Clear plastic cups
- 20 Small opaque bathroom sized cups
- 150 Clear straws
- 25 Flexible straws
- 15 600 mL Plastic beakers
- 5 100 mL Graduated cylinder
- 1 Small bottle of food coloring
- 5 Small buttons
- 5 Small corks
- 5 Wooden beads
- 5 Glass marbles
- 5 Pennies
- 2 Bags small rocks (at least enough for 350 mL per beaker)
- 2 Bags medium rocks (at least enough for 350 mL per beaker)
- 2 Bags large rocks (at least enough for 350 mL per beaker)
- 4 Bags of colored sand (not water proof)
- 10 Kitchen sponges
- 1 Turkey injector

Table of Contents

Standards Correlation Information

www.NEED.org/curriculumcorrelations

Next Generation Science Standards

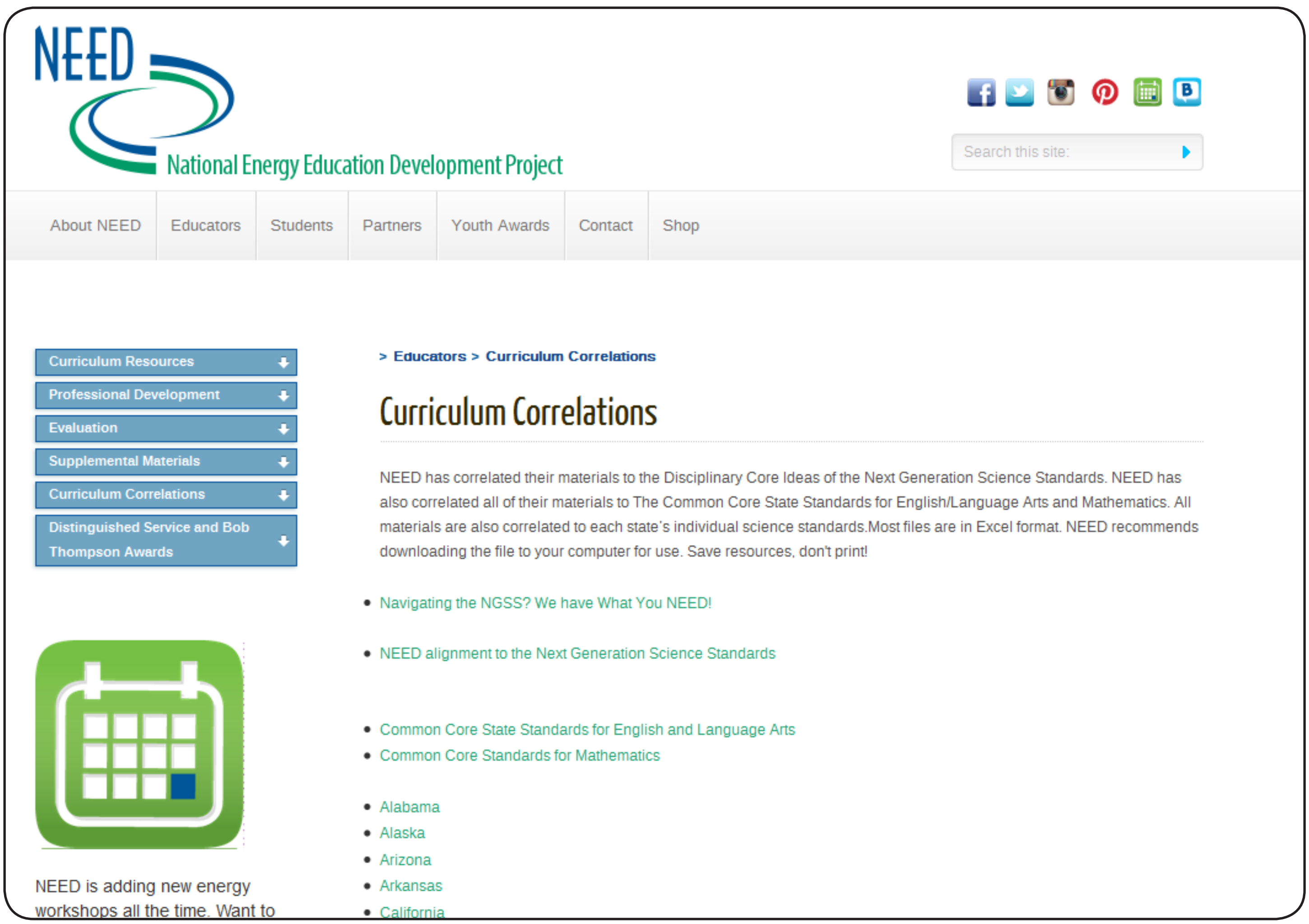
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's curriculum correlations website.

Common Core State Standards

- This guide has been correlated to the Common Core State Standards in both language arts and mathematics. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED curriculum correlations website.

Individual State Science Standards

- This guide has been correlated to each state's individual science standards. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED website.



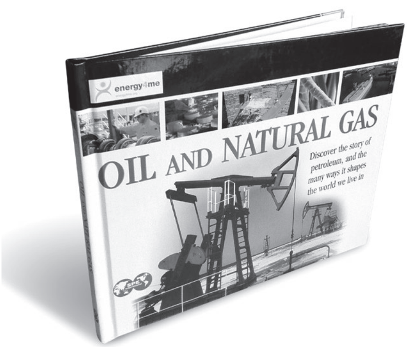
Wonders of Oil and Natural Gas Materials

The following is a list, by activity, of materials needed to complete the activities in this curriculum guide.

ACTIVITY	MATERIALS INCLUDED IN KIT	ADDITIONAL MATERIALS NEEDED
Exploring Density	▪Graduated cylinders ▪600 mL Beakers ▪Food coloring (not yellow) ▪Plastic buttons ▪Small corks ▪Pennies ▪Glass marbles ▪Wooden beads	▪Corn syrup ▪Water ▪Vegetable oil ▪Grapes or blueberries ▪Ice cubes
Exploring Porosity	▪Beakers ▪100 mL Graduated cylinders ▪Large rocks ▪Medium rocks ▪Small rocks ▪Food coloring (optional)	▪Water ▪Towels or paper towels
Formation of Petroleum and Natural Gas Listening Activity		▪Paper ▪Art supplies
Illustrating Stories		▪Construction paper ▪Art supplies ▪Binding materials—stapler, yarn, hole punch
Let's Take Core Samples		▪Yellow or white cake mix ▪White icing ▪Red, blue, and green food coloring ▪Foil cupcake liners ▪Cupcake pans or cookie sheet ▪Clear plastic straws cut in half—three per cupcake ▪Plastic knives—one per student
Drilling for Oil in the Ocean	▪Clear plastic straws ▪2 Cups of dark or colored sand	▪15 cm x 15 cm Piece of foam board ▪Clear tape ▪Paper ▪4 Sharpened pencils ▪10 Gallon aquarium or large plastic container ▪Large bag of light sand
Build a Stationary Oil Rig	▪Clear plastic straws	▪10 Gallon aquarium or large plastic container ▪Toothpicks ▪15 cm x 15 cm Foam board ▪Modeling clay ▪Sharp scissors ▪Water
Floating Oil Rig		▪10 Gallon aquarium (or large plastic container) filled with 20 cm of water ▪Small, empty glue bottles with twist-close tops ▪Small weights such as sinkers ▪15 cm x 15 cm Foam board ▪String or yarn

ACTIVITY	MATERIALS INCLUDED IN KIT	ADDITIONAL MATERIALS NEEDED
Perforated Well Casing	▪Kitchen sponges, the same size and shape ▪Flexible straws	▪Push pins ▪Shallow trays (for sponges) ▪Shallow trays (for collection from straw) ▪Plastic wrap ▪Heavy books or weights ▪10-20 mL Graduated cylinder ▪Water ▪Paper towels ▪Tape
Fracturing With Gelatin	▪Flexible straws	▪20 cc Syringe ▪Breakfast syrup ▪Plastic knife ▪Large disposable plates ▪Large (1 qt) measuring cup ▪Loaf pan (9 x 5) ▪Non-stick cooking spray ▪Plastic wrap ▪Push pins ▪Spatula ▪Unflavored gelatin ▪Wire whisk ▪Paper towels
Fracturing a Cake	▪Turkey injector	▪Frozen layer cake ▪Chocolate Magic Shell® sundae topping ▪Plastic knife ▪Cups or beakers (optional)
Volume Simulations	▪Inflatable beach ball ▪Ping pong ball ▪Counting units (cotton balls, bingo chips, blocks, etc.) ▪1,000 mL Beakers ▪Water	
I'm Made From Oil and Natural Gas		▪Large opaque container ▪Objects from your classroom made from oil and gas; examples: • Pen • Marker • Plastic ruler • Bingo chips • Plastic building bricks • Pencil erasers • Mechanical pencil • Sandwich or snack bag • Plastic grocery bag • Plastic food storage bag • Mouse pad • Transparency film • Lip balm • Hair brush or comb • 3-Ring binder

ACTIVITY	MATERIALS INCLUDED IN KIT	ADDITIONAL MATERIALS NEEDED
A Nifty Natural Gas Story		▪Art supplies and/or props
Pretzel Power		▪3 x 5 Cards ▪Bag of pretzels ▪Plastic sandwich bags ▪Three signs (Home, Near Town, Far Town) ▪Scissors ▪Glue ▪Internet access for students (optional)
Sources of Energy Math		▪Calculators ▪Art supplies



Oil and Natural Gas, from the Society of Petroleum Engineers, is a great resource that supplements the information and activities in *Wonders of Oil and Natural Gas.* Available in several languages, this book showcases the geology, technology, careers, and difficult concepts of oil and natural gas in a fun, colorfully illustrated, and informational way.

To order a free classroom copy, visit http://www.energy4me.org/order/oil-and-natural-gas/.

Teacher Guide

Grade Level

- Elementary, grades 3-5

Time

- Approximately 10-15 class periods, depending upon the extent of activities you choose to utilize in the unit

Science Notebooks

Throughout this curriculum, science notebooks are referenced. If you currently use science notebooks or journals, you may have your students continue using them. A rubric to guide assessment of student notebooks can be found on page 26.

In addition to science notebooks, student worksheets have been included in the guide. Depending on your students' level of independence and familiarity with the scientific process, you may choose to use these instead of science notebooks. Or, as appropriate, you may wish to make copies of worksheets and have your students glue or tape the copies into their notebooks.

Additional Resources

NEED has many other resources that can be used in the classroom to enhance student learning or as additional background for the unit. Visit www.NEED.org to find these titles and more:

- *Fossil Fuels to Products*
- *Energy on Stage*
- *Energy Live!*
- *Energy Stories and More*
- *Elementary Energy Infobook*

Background

Wonders of Oil and Natural Gas is a hands-on exploration unit focused on the oil and natural gas industry. A list of materials is given at the beginning of the unit, and reproducible student informational text and activity pages are also included.

★Concepts

- Oil and natural gas are nonrenewable fossil fuels. Natural gas is a clear, colorless, odorless gas made primarily of methane. Oil is a liquid mixture of hydrogen and carbon molecules.
- Oil and natural gas formed over hundreds of millions of years when microscopic marine plants and animals were buried under rocks and sediment. The plant and animal remains did not decompose in the usual way. The result is an energy-rich mixture of gases and liquids.
- Oil and natural gas were used by many ancient cultures as a source of light or heat.
- Oil and natural gas are found deep underground using a variety of equipment and techniques. They are reached by drilling through rocks. Oil is pumped and shipped to a refinery for further processing, and natural gas is pumped under pressure through a pipeline to its points of use.
- Natural gas is used primarily as a source of heat in industry and residences and also as an energy source in electric power plants.
- Products made from oil are used for transportation fuels, waxes and tars, to make plastics, and for home heating in rural areas (propane).

Preparation

- Pre-read the student and teacher sections. Decide which activities you will conduct to reinforce the information presented in the nonfiction text.
- Gather the necessary materials from the kit for the activities you have chosen. A chart can be found on pages 5-7. The activities are designed so that most of the additional required materials are easily available in the school science lab, or can be obtained easily at hardware, pet, and craft stores. If you have difficulty locating any of the materials you need, please e-mail NEED at info@need.org for information on where you can purchase the materials.

Introduction

1. Begin the unit with a brief discussion of energy. Ask students to brainstorm a list of things they know about oil, natural gas, and energy. Instruct them to fill out the oil and natural gas KWL chart on page 29 with facts they know and want to know.
2. Have students read the student informational text and discuss the information presented. As they read, have students fill in what they learned on their KWL chart. Students may also complete the reading as a jigsaw. Students can be divided into groups to read about different topics within the text and share what they learned with groups or the class.

Activity 1: Exploring Density

Background

Oil and natural gas can often be found together in a rock formation. Density is an important property for oil and natural gas. These two materials have different densities and can be separated from each other and from other materials when heated or allowed to settle.

Objective

- Students will be able to describe how objects separate by density, listing or describing a common example.

Time

- 30-45 minutes

Materials *FOR EACH GROUP*

- Graduated cylinder
- 600 mL Beaker
- Corn syrup
- Water
- Vegetable oil
- Food coloring (not yellow)
- Plastic button
- Grape or blueberry
- Small cork
- Penny
- Glass marble
- Ice cube
- Wooden bead or wooden button

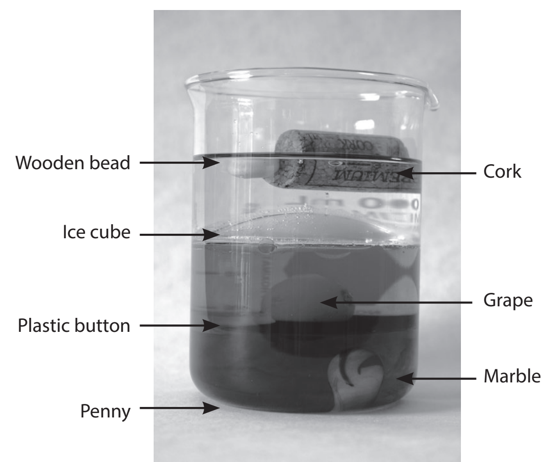
***NOTE**: Students need to have enough oil, water, and corn syrup so that they have at least a 2-3 cm layer in their container. The smaller the diameter of your container, the less you will need. Decide on the container and amount for your students to measure before beginning the lab. Substitute objects can be used where necessary.*

Materials *FOR EACH STUDENT*

- *Exploring Density* worksheets, pages 44-45

Preparation

- Make copies of the worksheets for each student.
- Add 1 or 2 drops of food coloring to the corn syrup and mix thoroughly. Do not make the color too dark, as students need to be able to see objects in it easily.
- Add 2 or 3 drops of a different color of food coloring to the water and mix thoroughly. Like the corn syrup, students will need to be able to see through it. If choosing to also dye the vegetable oil, you will need a special food grade dye for this.
- Set up materials from the list above into lab stations so that each group has access to all of the objects.



✔ Procedure

1. Distribute the activity to students and have them read the background information independently or as a whole group.
2. Discuss the concept and/or definition of density and answer any questions students might have.
3. Briefly give an overview of the activity.
4. Caution students that oil will make the glass containers slippery, so they should handle them very carefully.
5. Dismiss students to their lab stations to complete the activity.
6. When they are finished, students should wash their containers thoroughly with dish soap. They may also wash the objects, except for the ice cube and fruit.
7. Instruct students to return to their seats and answer the questions.
8. Discuss as a class.

Extension

- Before students empty their liquid density columns, they may want to try other objects. With your approval, they can drop other objects into the liquids and compare their densities, too. This information should be recorded along with their results in their science notebooks or on their worksheets. Ask students about things they encounter in their daily lives that separate by density. One good example is Italian salad dressing, but anything that must be shaken before it is used is a valid example.

Activity 2: Exploring Porosity

Background

Porosity is an important property of rocks. Geologists study the porosity of rocks in order to locate areas and rocks where pertroleum and natural gas can be found. Rocks have pores that can hold liquid or gas much like a sponge holds water. Certain rocks, like sedimentary rocks, are likely to be porous, and therefore are more likely to contain oil and natural gas.

✪ Objective

- Students will be able to define and describe porosity as a property of rocks.

Time

- 45-60 minutes

Materials *FOR EACH GROUP*

- 3 Beakers (400-600 mL)
- Water
- 100 mL Graduated cylinder
- Large rocks
- Medium rocks
- Small rocks
- Towels or paper towels
- Food coloring (optional)

Materials *FOR EACH STUDENT*

- *Exploring Porosity* worksheets, pages 46-47

Preparation

- Make copies of the worksheets for each student.
- Add a few drops of food coloring to the water so it is easier to see.
- Set up lab stations with the materials available for students.
- Set up areas with towels spread out or strainers for the rocks to drain and dry when finished for re-use.

✔ Procedure

1. Distribute the activity to students and have them read the background information independently or as a whole class.
2. Discuss porosity and answer any questions students may have.
3. Show students the marking on the beaker they should use as the fill line.
4. Alert students to carefully drop the materials into the beaker, to prevent the glass from breaking. Demonstrate this, if necessary.
5. Dismiss students to their lab stations to complete the activity.
6. When students are finished, have them clean up their stations. Direct students to take their materials to the "drying stations" you have prepared. Make sure to keep the substances separated.
7. Discuss porosity and student results on the activity. Review how density and porosity are important to oil and natural gas.

Extension

- Hold up clear plastic bags of other objects not used by students. Ask them to predict in their science notebooks how the porosity of the objects would compare to the three they used. Have them use their experimental data to support their predictions.

Activity 3: Formation of Petroleum and Natural Gas Listening Activity

✪ Objective

- Students will be able to describe how petroleum and natural gas formed, drawing pictures to show their understanding.

Time

- 30-45 minutes

Materials *FOR EACH GROUP*

- 8 ½" x 11" Sheets of paper
- Art supplies

Materials *FOR EACH STUDENT*

- *Formation of Petroleum and Natural Gas Listening Activity* worksheet, page 48

Preparation

- Make copies of the worksheet for each student, if necessary. This can be conducted without using a student sheet. Students with processing delays may benefit from having the student sheet with the script in front of them.
- Gather materials for each student.
- Depending on the level of your students, it may be helpful to pre-fold sheets of paper, or mark one page off into thirds, label it, and make copies.

✔ Procedure

1. Have students clear everything off their desks except for colored pencils.
2. Give each student a sheet of paper. Instruct the students to divide the paper into three equal parts. Label the sections: Scene 1, Scene 2, Scene 3.
3. Tell students you are going to read a story to them twice. The first time you read it, tell them to just listen. The second time you read it, you will give them time to illustrate and you will model what can be drawn.
4. Tell students to label the three sections at the bottom with the following labels: "300 to 400 million years ago," "50 to 100 million years ago," and "Today."
5. Read the story below one time and when you're finished, tell them you will read it again but give them about 5 minutes to illustrate each scene.
6. If necessary, model how to make the different lines for the layers of rock on each section of the paper. Read each scene and then give students around 5 minutes or less to draw the pictures. Copies of the formation diagram, like the one on page 34, are available at www.NEED.org in the graphics library if you wish to print them.
7. Compare and discuss illustrations.

Formation of Petroleum and Natural Gas

Scene One—300 to 400 million years ago, a large sea covered the area we now know as the southern part of the United States. In this sea lived a large number of microscopic or tiny plants and animals, called plankton. When the plants and animals died they were buried on the ocean floor and then covered with layers of sediment and rock.

Scene Two—50 to 100 million years ago the remains of the microscopic plants and animals were buried deeper and deeper. Enormous amounts of heat and pressure turned them into petroleum and natural gas.

Scene Three—Today we drill through the layers of sedimentary rock to reach the rock layers that contain oil and natural gas deposits.

Extensions

- Have students collaborate to make a very large class picture of their scenes. They could each add a little bit to the drawings, or they can elect students to do the drawing, while describing what should be written. Loan the picture to classrooms of students who are not yet reading.
- Ask students what additional scenes of the oil and natural gas process they would like to describe and illustrate. Have them choose one and write out the words that would be read, and illustrate the scene.

Activity 4: Illustrating Stories

Objective

- Students will be able to describe petroleum and natural gas formation, exploration, and production by illustrating a story.

Time

- Approximately 30-60 minutes

Materials

- Construction paper
- Art supplies
- Binding materials—stapler, yarn, hole punch
- Copy of the *Illustrating Stories* worksheet, page 49
- Copies of the stories *Under the Sea* and *Into Deep Water: Drilling For Oil and Natural Gas*, pages 50-55

Preparation

- Make copies of the worksheet and stories for each student.
- Decide how many pages you want students' stories to be. Decide if you will write or type the words for the students as you go, or have that done before they add illustrations. You may also project the stories and have students write the text themselves.

✔ Procedure

1. Read the stories to the class or have students read independently. Discuss each story.
2. Assign students to groups. Have each group illustrate the pages you provide them. You may choose to use existing reading groups you have already set up.
3. Collect the finished pages and bind the book with staples or colorful yarn. Read the finished story again, letting all students see the finished product.

OPTIONAL: Students could also work individually to illustrate and create their own books.

Extensions

- Have students write and illustrate their own energy stories.
- Have students read their stories to another class.

Activity 5: Let 's Take Core Samples

✪ Objective

- Students will be able to describe a core sample and explain how it might be helpful for geologists when exploring for oil and natural gas.

Time

- 30-40 minutes to prepare cupcakes
- 20-30 minutes for the activity in class

Materials *FOR CUPCAKE PREPARATION*

- Yellow or white cake mix
- White icing
- Red, blue, and green food coloring
- Foil cupcake liners
- Cupcake pans or cookie sheet
- Paper towels

Materials *FOR EACH STUDENT*

- Three clear plastic straw halves
- Plastic knife
- *Let's Take Core Samples* worksheets, pages 56-57

***NOTE:** For an alternative set-up, use the intermediate version of this activity, *Exploring Core Sampling*, found in NEED's *Exploring Oil and Natural Gas* guide. This version utilizes the sand included in the Oil and Natural Gas kit. Download the guide at shop.need.org.

Preparation

- Make copies of the worksheets for each student.
- Combine the cake mix according to package directions. Separate the batter into at least 3 bowls. Add blue food coloring to one bowl and red to the other. Spoon the batter into the cupcake liners, one tablespoon of each color in varying layers. The goal is to make uneven layers and each cupcake different.
- Bake the cupcakes according to package directions and cool. Keep the foil liners on the cupcakes to keep the layers of colors hidden.
- Divide the icing into two bowls. Color one bowl of icing blue and the other green with food coloring.
- Decorate cupcakes with blue icing representing water, or green icing representing land, or a combination of the two.

✔ Procedure

1. Explain to students that geologists take core samples of the earth to help them find rock layers that hold oil or natural gas deposits.
2. Distribute a copy of the activity, and one cupcake to each student. Tell students not to do anything with the cupcake. Explain to them how you prepared the cupcakes. Make sure their cupcake stays on top of the paper towel to contain messes.
3. Assign each color of the cupcake layers to a different type of rock— sedimentary, metamorphic, and igneous. Review that petroleum is found in or around sedimentary rock using page 35 in the student text if necessary.
4. Give each student three clear plastic straw halves, and direct them to begin the activity.
5. Have the students complete the activity.
6. Review and discuss core sampling, student observations, and results. Discuss with the class the importance of the exploration process, and what difficulties they might encounter when exploring.

Extensions

- Instead of cupcakes, make one large cake for the whole class.
- Have students research how core samples are taken, and how many core samples are taken before a well is drilled.
- Invite a petroleum professional or geologist into your classroom to talk about oil or natural gas exploration.

Activity 6: Drilling for Oil in the Ocean

Objective

- Students will be able to use a model to demonstrate and describe drilling for oil offshore (in the ocean).

Time

- 45 minutes

Materials

- 15 cm x 15 cm Piece of foam board
- Clear plastic straws
- Clear tape
- Paper
- 4 Sharpened pencils
- 10 Gallon aquarium or large plastic container
- Large bag of light sand
- 2 Cups of dark or colored sand
- *Drilling for Oil in the Ocean* worksheet, page 58

Preparation

- Make copies of the worksheet for each student.
- Pour three mounds of dark sand randomly on the bottom of the aquarium to serve as oil deposits.
- Draw a map marking the locations of the three deposits with "Xs" and display it on the board.
- Cover the entire bottom of the aquarium with several inches of light sand to resemble the ocean floor.
- Carefully fill the aquarium with five inches of water, taking care not to disturb or move the sand drastically.
- Cut a 1" hole in the middle of the foam board.
- Insert one sharpened pencil into each corner of the foam board, as legs for the rig.
- Carefully place the rig in the water. The deck (foam board) should be slightly above water level.

✔ Procedure

1. Give each student two straws and a piece of tape. Have each student tape the straws together end to end so that the juncture is completely sealed.
2. Explain to the students that the straws are going to represent their drills. They will drill for oil using the map you created as a guide.
3. Give each student one chance to strike oil by inserting his/her drill through the hole in the platform and into the sand until it hits the bottom of the aquarium. The students will cover the end of the straw tightly with one finger and remove the straw. They should try to find the dark sand, which represents the oil.
4. Review and discuss conclusion questions and what difficulties students encountered trying to drill for oil.

Extensions

- Ask students to describe how the model is similar to the ocean, and how it is different. Students can list these thoughts in their science notebooks or you can list them on the board or on a large piece of paper for the class.
- Locate pictures or video of an actual ocean drilling platform and show these to students. Discuss similarities and differences of your model.

Activity 7: Build a Stationary Oil Rig

Objective

- Students will be able to use a model to describe how a stationary rig is placed into the ocean.

Time

- 30-50 minutes

Materials

- 10 Gallon aquarium or large plastic container
- 4 Clear plastic straws
- 4 Toothpicks
- 15 cm x 15 cm Piece of foam board
- Modeling clay
- Sharp scissors
- Water
- *Build a Stationary Oil Rig* worksheet, page 59

Preparation

- Make copies of the worksheet for each student.
- Cut two half-inch slits near the bottom of each straw with sharp scissors. These will act as valves.
- Poke holes in the corners of the board.
- Fill the aquarium with 15 cm of water.

✔ Procedure

1. Explain to students that in this demonstration they will be looking at a stationary oil rig. Ask them what they think stationary means.
2. Give each student a copy of the worksheet and follow the procedure using students to help.
3. Enlarge pencil holes in the platform if needed. As water fills the legs, the feet should sink to the bottom and the rig should right itself.
4. Experiment with the amount of clay to use on each foot for the demonstration to proceed smoothly.
5. Have students answer questions and revisit what stationary means.

Extensions

- Have students compare/contrast a stationary oil rig with a drilling rig from the previous activity.
- Find photographs or video of a stationary oil production platform and show these to students. Ask them what is the same, and what is different, from the pictures or video you showed them after Activity 6: Drilling for Oil in the Ocean.

Activity 8: Floating Oil Rig

Objective

- Students will be able to use a model to describe how a floating oil rig works.

Time

- 30-50 minutes

Materials

- 10 Gallon aquarium (or large plastic container) filled with 20 cm of water
- 4 Small empty glue bottles with twist-close tops
- 8 Small weights such as sinkers
- 15 cm x 15 cm Foam board
- String or yarn
- *Floating Oil Rig* worksheet, page 60

Preparation

- Make copies of the worksheet for each student.
- Poke two holes near the bottom of each glue bottle.
- Poke holes in the corners of the foam board.

✔ Procedure

1. Explain to students that in this demonstration they will be looking at a floating oil rig. Ask them what differences they think their model might have compared to the previous model of a stationary rig.
2. Give each student a copy of the worksheet and follow the procedure using students to help.
3. Place the rig in the aquarium.
4. Adjust the water level in the aquarium if the weights don't reach the bottom.
5. By opening the tops of the glue bottles, you can regulate the amount of water in the bottles. This ballast mechanism is used to keep the platform flat. It also makes sure the platform is the right distance from the water when heavy machinery is added or taken away from the rig. You can experiment by adding weight to the platform.
6. Have students answer questions and discuss how floating and stationary rigs are different and how each is similar.

Extensions

- Ask students when a floating rig would be more appropriate than a stationary rig. Have them list circumstances that are ideal for each type of rig.
- Find out where floating rigs and stationary rigs are located in the Gulf of Mexico. Have students research each and report back to the class the underwater topography, water depth, and amount of petroleum produced by their respective rigs.

Activity 9: Perforated Well Casing

Background

A vertical oil or natural gas well has only one opening once it is drilled — at the bottom. In some formations it is helpful to perforate the well casing in order to increase the number of places liquids can flow into the well casing. Perforations are used when drilling vertically, but are also extremely helpful when drilling horizontally, as in the process of hydraulic fracturing. Perforated well casings can help to produce 3-5 times more oil and natural gas by increasing the number of openings for oil and natural gas to enter the well.

Objective

- Students will be able to describe the importance of perforation in the process of drilling.

Time

- 30-50 minutes

Materials *FOR EACH GROUP*

- 2 Kitchen sponges, the same size and shape
- Flexible straw
- Push pin
- Shallow tray or plate (for sponges)
- Shallow tray or plate (for collection from straw)
- Plastic wrap
- 1-3 Heavy books or weights
- 10-25 mL Graduated cylinder
- Water
- Tape
- Paper towels

Materials *FOR EACH STUDENT*

- *Perforated Well Casing* worksheets, pages 61-62

Preparation

- Make copies of the worksheets for each student.
- Gather materials for the activity and set up lab stations for students.

✔ Procedure

1. Distribute the activity and discuss with students what the word perforate means.
2. Explain the activity instructions, demonstrating the set-up.
3. Instruct students to begin. Assist with clean-up when finished.
4. Discuss how perforations could improve the results of drilling.

Extension

- Ask students to re-design the activity to create a better model of perforated casings and horizontal drilling.

Activity 10: Fracturing With Gelatin

Background

Some rock types, like shale, have many pores, but the pores are very small and tightly lock oil and natural gas inside. Drilling to retrieve these hydrocarbons is often not enough. In this circumstance, hydraulic fracturing or "fracking" is used to break up the rock to allow oil and gas to flow easily. This activity demonstrates how fluid can be used to fracture or create cracks in the rock. Gelatin, unlike rock layers, however, will not hold the fluid inside. Gelatin blocks can be prepared the night before the activity or even further ahead of time and refrigerated until used in class. The instructions below prepare 2-3 blocks of gelatin. Adjust the recipe to accommodate more students if needed.

✪ Objective

- Students will be able to explain that fractures are created when using liquids under pressure.

Time

- 30-50 minutes

Materials *FOR EACH GROUP*

- 20 cc Syringe
- Breakfast syrup
- Plastic knife
- Large disposable plate
- Flexible straws
- Push pin
- Plastic wrap
- Paper towels
- Warm water

Materials *FOR GELATIN PREPARATION*

- Large (1 qt) measuring cup
- Loaf pan (9 x 5)
- Non-stick cooking spray
- Unflavored gelatin
- Wire whisk
- Spatula
- Water

Materials *FOR EACH STUDENT*

- *Fracturing With Gelatin* worksheets, pages 63-64

Preparation

- Prepare gelatin blocks according to the following instructions:
    - Fill the large measuring cup with ½ cup of water.
    - Sprinkle 3 packets of gelatin over the water and swirl to mix.
    - Add boiling water to the gelatin to fill to four cups. Whisk to dissolve the gelatin.
    - Spray the bottom of the loaf pan with cooking spray and pour the hot gelatin solution into the loaf pan.
    - Refrigerate overnight.
- Make copies of the worksheets for each student.
- Gather materials for students and set up lab work stations.

✔ Procedure

1. Cut the gelatin into blocks and, using the spatula, distribute a block to each student group.
2. Discuss the activity and instructions with students.
3. Have paper towels and warm water available to assist with clean-up.
4. Discuss how the fractures formed in each gelatin block and what the syrup did as a result. Connect student observations to the process of fracking, reveiwing the informational text, as necessary.
5. Discuss what other materials students may wish to "frack" into that might hold the fluid inside.

Activity 11: Fracturing a Cake

Background

This activity demonstrates how a fracking fluid can be held in the pores of rock once cracks or fissures are created. The Magic Shell® topping can move from pore to pore and spread out. As the fluid is exposed to the cold cake it hardens to resemble the way a fracking fluid can hold the pores open with coagulants (like sand) that allow natural gas to flow through them. A fracking fluid doesn't harden as the fluid does in this demonstration, but the cracks are held open. The icing on the cake is of a different density than the cake, and the sundae topping will not flow through it, just as a fracking fluid will not flow into non-porous rock of differing density.

✪ Objective

- Students will be able to describe how liquid can move through the pores of a solid.

Time

- 20-30 minutes

Materials *FOR EACH GROUP*

- Piece of frozen layer cake
- Turkey injector
- Chocolate Magic Shell® sundae topping
- Cup or beaker (optional)
- Plastic knife

Materials *FOR EACH STUDENT*

- *Fracturing a Cake* worksheets, pages 65-66

Preparation

- Make or purchase a layer cake and freeze it. Pre-prepared frozen layer cakes work very well.
- Gather materials for students, and set up lab work stations. Pre-assemble the injectors for students.
- Make copies of the worksheets for each student.

✔ Procedure

1. Cut the cake into pieces for your students so that each student or pair has an end with icing to frack into.
2. Distribute materials. Remind students to use caution with the injectors.
3. Remind students to keep their sundae topping moving around in their cup or beaker, or it will harden.
4. Review student observations and discuss how the fracking fluid (sundae topping) did or did not move throughout layers of the cake.

Activity 12: Volume Simulations

Background

After oil and natural gas are separated they are transported for further processing and use. If natural gas must travel a long distance it can be liquefied from its gaseous state. When it is cooled to turn into a liquid it takes up less space, making it easier to transport for long distances. We call liquefied natural gas LNG.

Objectives

- Students will be able to explain how volume changes when a substance is changed from a gaseous state to a liquid state, and vice versa.
- Students will be able to quantitatively describe the volume difference between natural gas and LNG.

Time

- 20-30 minutes

Materials

- Beach ball
- Ping pong ball
- 1 Set of 600 counting units (or any item such as cotton balls) for each group
- 1,000 mL Beaker for each group
- Water

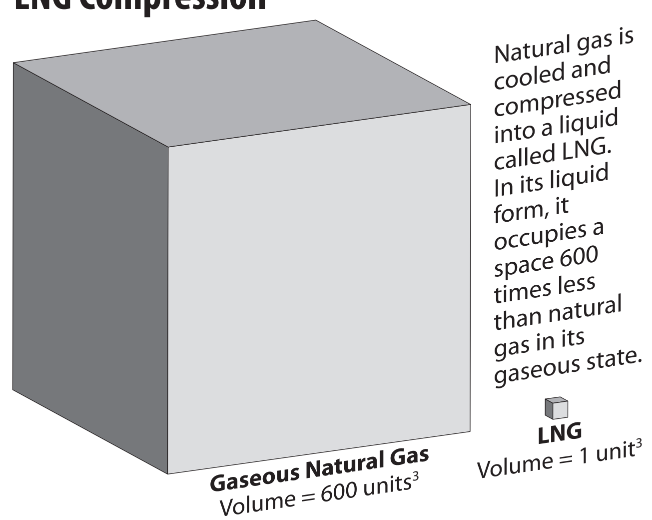
Preparation

- Gather the materials above.
- Divide the students into groups of three to five.
- Fill each beaker with 1 mL of water.

Procedure

1. Show the students the beach ball and the ping pong ball. Ask them which ball they think represents natural gas and which represents LNG. The beach ball represents a gaseous state [natural gas] while the ping pong ball represents the liquid state [LNG]. Ask students to write and explain their reasoning.
2. Explain to the students that natural gas is typically found in a gaseous state. Explain that natural gas can be changed into a liquid (LNG) by making it very cold (-260°F or -162.2°C).
3. Ask the students what happens to the volume of a gas when it becomes a liquid. (The volume of a gas is reduced when it is a liquid.)
4. Revisit the ping pong ball and beach ball. Ask students to edit their reasoning from before, as necessary.
5. Pass out the 600 unit sets, one per group. Allow time for the students to determine how many units are in each set. Ask the students to predict the volume of natural gas in a liquid state (LNG) if the whole set represents a gaseous state. Have the groups set aside the number of units they predict.
6. Gather predictions from the groups and write them on the board or interactive board.
7. Explain to the students that LNG is 1/600th of the volume of natural gas in a gaseous state. Have the students separate out the correct number of units to represent LNG. (One unit) Collect the unit sets from the groups.

LNG Compression



CONTINUED ON NEXT PAGE

8. Pass the beakers with 1 mL of water to each group. Have the students predict or draw a line on the beaker (with pencil or an erasable marker) to show how much water would represent natural gas in a gaseous state, if the amount of water presently in the beaker represents LNG. (600 mL) Collect the beakers.

Extensions

- Have students create additional visual natural gas and LNG volume comparisons and demonstrate them.
- Have students list possible advantages and disadvantages to natural gas in both a gaseous state and a liquid state.

Activity 13: I'm Made From Oil and Natural Gas

Objective

- Students will be able to list materials made from petroleum and natural gas.

Time

- 40-50 minutes

Materials *FOR EACH GROUP*

- Large opaque container
- 20-30 Objects from your classroom made from oil and natural gas; examples:
  - Pen
  - Marker
  - Plastic ruler
  - Bingo chips
  - Plastic building bricks
  - Pencil erasers
  - Mechanical pencil
  - Sandwich or snack bag
  - Plastic grocery bag
  - Plastic food storage bag
  - Mouse pad
  - Transparency film
  - Lip balm
  - Hair brush or comb
  - 3-Ring binder

Materials *FOR EACH STUDENT*

- *I'm Made From Oil and Natural Gas* worksheets, pages 67-68

Preparation

- Make copies of the worksheets for each student.
- Gather objects from your classroom and place them into the container. Set the container out of sight until you begin the activity.

OPTIONAL: You may decide to also add a few items NOT produced from petroleum and natural gas.

✔ Procedure

1. Pour the contents of the container out onto a table or desk. Give students a few minutes to look at the objects.
2. Put the objects you collected back in the container.
3. Have students list as many items as they can recall that they think are made from petroleum and natural gas.
4. Go over the students' lists. Tell students which items in the container were made from petroleum and natural gas.
5. Have students look around the classroom and make a class list of all the things they see that are made from oil and natural gas.

Extensions

- Have students make lists of objects they use at home that are not found at school, that are made from oil or natural gas.
- Have students select one object and research the manufacturing of that object, from petroleum refining all the way through to the finished product. Students can report their findings in a number of ways, whether orally, digitally, in a written report, or in poster format.

Activity 14: A Nifty Natural Gas Story

Background

When students think of energy, they most often are thinking of electricity; however, a significant proportion of our total energy is supplied by natural gas, and as more natural gas is unlocked from shale deposits, that proportion will continue to increase. The purpose of this activity is to help students understand how natural gas is used in the energy industry and how we can use it as consumers. Students will also identify the energy transformations of natural gas from formation to end use.

Objective

- Students will be able to explain the energy transformations or flows involved with natural gas, from production to use.

Time

- 40-60 minutes

Materials

- Art supplies or props as listed
- *A Nifty Natural Gas Story Pantomime*, page 69
- *A Nifty Natural Gas Story* master, pages 70-71
- *Forms of Energy* master, page 30
- *Energy Transformations* master, page 31

Preparation

- Make a copy of *A Nifty Natural Gas Story Pantomime* for each student.
- Provide art supplies for students to assemble their props, or gather the suggested items or reasonable substitutes as shown on the handout.
- Prepare copies of the masters to project.

✔ Procedure

1. Review the forms of energy with the class. Project the master to add to class discussion.
2. Explain and/or review energy transformations using the master as a visual. Discuss the forms of energy in each part of the transformation.
3. Explain to the class that energy transformations allow us to use our energy sources for electricity, to power vehicles, and to heat/cool our homes.
4. Assign students to a specific role on the pantomime sheet.
5. Discuss how natural gas is produced, processed, transported, and used.
6. Have each student assemble his/her props, or provide each student with a suggested prop.
7. Review or introduce any new vocabulary as needed. Project the story. Act out the story from beginning to end. Extra students may help read the story aloud.
8. Substitute in different students or props as necessary.
9. Ask students to write an essay explaining the energy flow involved to produce electricity from natural gas.

Extension

- Have students substitute different energy sources into the energy flow, creating a new story, props, and outcome for each.

Activity 15: Pretzel Power

✪ Objective

- Students will be able to describe the energy efficiency of different kinds of transportation and list the benefits of carpooling.

Time

- 30-60 minutes

Materials

- 3 x 5 Cards
- Internet access for students (optional)
- Bag of pretzels
- Plastic sandwich bags
- Three signs (Home, Near Town, Far Town)
- *Pretzel Power* worksheet, pages 72-73
- Scissors
- Glue

Preparation

- Make copies of the worksheets for each student.
- Prepare a plastic bag with ten pretzels for each student.
- Make three signs, one labeled "Home" one labeled "Near Town" and one labeled "Far Town." The signs should be large enough to see from across the room.
- Select a large area and place the Home, Near Town, and Far Town signs on poles or walls. The distance to Near Town should be 50 steps. The distance to Far Town should be 100 steps. (Do not give these distances to students.)

✔ Procedure

1. Have students look up a car they would like to drive on www.fueleconomy.gov. On 3" x 5" cards, students should record the car's name, model year, miles per gallon, and the number of passengers the car holds. It may be helpful, if students have chosen a FFV (flex fuel vehicle), that they choose which fuel they will use—gasoline or E85—before recording mileage.

   NOTE: If you would prefer, you can print the pre-made automobile cards (page 74-86) and students can choose a car from the list. If you would like to print the cards on sticky labels use Avery 5392. Students can stick the labels onto their shirts or notecards. When handing out cards for vehicles using Flex Fuel, assign the fuel choice to the student.
2. Distribute a bag of pretzels to each student. Tell students not to eat the pretzels until they are instructed to begin.
3. Explain to the students that each pretzel represents one gallon of gasoline, and each step (heel-to-toe) the student takes represents one mile traveled.
4. Students eat a pretzel and take the appropriate number of steps before eating the next pretzel. All steps are heel-to-toe.

❶ Round One

- Use only 5 pretzels for this round. Each person will drive his/her car to work in Near Town and return Home. If anyone runs out of fuel (pretzels), he/she must stay at that point until round one is over. Line up at Home and start stepping!

  DISCUSS: Which cars got you to work and home? Which didn't?
  - Did anyone have extra fuel remaining?
  - What alternatives to driving your own car are there?

❷ Round Two

- Using the remaining five pretzels, try some of the alternative suggestions discussed above. Everyone will travel to Far Town and return Home. Expect "negotiations." Suggest students carpool to work. Drivers may eat each passenger's pretzels as fuel. Line up at Home and start stepping!

  DISCUSS: Who made it to Far Town and back? How did you do this?
  - Who did not make it to Far Town and back? Why not?

NOTE: If students choose to use dedicated electric vehicles, they would have a shorter range they would be able to travel, despite higher MPGe ratings. Discuss with students how the game would have changed if they chose those vehicles and could only travel 30 to 60 miles at a time before refueling.

Activity 16: Sources of Energy Math

✪ Objective

- Students will be able to describe oil and natural gas as important sources in our economy using mathematical operations.

Time

- 30-50 minutes

Materials *FOR EACH GROUP*

- Calculators
- Art supplies
- *Energy Source Use Circle Graph* and *Oil and Natural Gas Math*, pages 87-88

Preparation

- Make copies of the worksheets for each student.

✔ Procedure

Option 1

1. Review basic math skills with students (percentages, graph interpretation, solving word problems, etc.), and the difference between renewable and nonrenewable sources.
2. Divide students into ability groups. Students who struggle more with math can be given the circle graph activity. Students who excel in math can be given the word problem activity.
3. Have students work independently or pair with others to share, compare, and correct answers if needed.

Option 2:

1. Review basic math skills with students (percentages, graph interpretation, solving word problems, etc.), and the difference between renewable and nonrenewable sources.
2. Work through problems individually with students, going over answers and giving students an opportunity to solve on their own when ready.

☑Answer Keys

Energy Source Use Circle Graph

1. petroleum
2. 9
3. 91
4. 82
5. >91

****NOTE:*** Sum of energy sources does not equal 100% due to independent rounding.

Oil and Natural Gas Math

1. 1,155,000 gallons
2. 480 gallons
3. a. 57,750 gallons
   b. 133.7 cars
4. 144.4 trucks
5. 38.5 cars

☑Evaluation

- Evaluate individual student performance using the graphic organizers and their student guides or science notebooks. A rubric is found on page 26.
- Play *Oil and Natural Gas Bingo* as a formative assessment piece or introduction/closing to the unit. Instructions are found on pages 27-28.
- Evaluate the entire unit with your students using the *Evaluation Form* on page 95 and return it to NEED.

Grading Rubric

Student Guide/Science Notebook Rubric

GRADE	SCIENTIFIC CONCEPTS	SCIENTIFIC INQUIRY	PRESENTATION
4	Student demonstrates thorough understanding of concepts through pictures, writing, and verbal communication.	Student is able to follow all steps of the scientific process: predicting, observing/recording data, and drawing a more complex conclusion related to his/her data. Student shows higher level thinking by asking his/her own questions.	Handwriting is legible. Pictures are realistic and include labels. All parts of the assignment are complete.
3	Student demonstrates understanding of concepts through pictures, writing, and/or verbal communication.	Student is able to predict, observe/record data, and draw a basic conclusion.	Handwriting is legible. Pictures are realistic and include most labels. All parts of the assignment are complete.
2	Student demonstrates a beginning understanding of concepts, may have a couple of lingering misconceptions.	Student is able to do two of the following: predict, observe/record data, draw conclusions.	Words and/or pictures may be hard to decipher at times. Pictures are present but are missing labels. The notebook has some missing components.
1	Student demonstrates confusion about concepts. Many misconceptions remain.	Student is able to do one or fewer of the following: predict, observe/record data, draw conclusions.	Words and/or pictures are hard to decipher. They may not be connected to the investigation. The notebook has many missing components.

Oil and Natural Gas BINGO Instructions

Get Ready

Duplicate as many *Oil and Natural Gas Bingo* sheets (found on page 89) as needed for each person in your group. In addition, decide now if you want to give the winner of your game a prize and what the prize will be.

Get Set

Pass out one *Oil and Natural Gas Bingo* sheet to each member of the group.

Go

PART ONE: FILLING IN THE BINGO SHEETS

Give the group the following instructions to create bingo cards:

- This bingo activity is very similar to regular bingo. However, there are a few things you'll need to know to play this game. First, please take a minute to look at your bingo sheet and read the 16 statements at the top of the page. Shortly, you'll be going around the room trying to find 16 people about whom the statements are true so you can write their names in one of the 16 boxes.
- When I give you the signal, you'll get up and ask a person if a statement at the top of your bingo sheet is true for them. If the person gives what you believe is a correct response, write the person's name in the corresponding box on the lower part of the page. For example, if you ask a person question "D" and he or she gives you what you think is a correct response, then go ahead and write the person's name in box D. A correct response is important because later on, if you get bingo, that person will be asked to answer the question correctly in front of the group. If he or she can't answer the question correctly, then you lose bingo. So, if someone gives you an incorrect answer, ask someone else! Don't use your name for one of the boxes or use the same person's name twice.
- Try to fill all 16 boxes in the next 20 minutes. This will increase your chances of winning. After the 20 minutes are up, please sit down and I will begin asking players to stand up and give their names. Are there any questions? You'll now have 20 minutes. Go!
- During the next 20 minutes, move around the room to assist the players. Every five minutes or so tell the players how many minutes are remaining in the game. Give the players a warning when just a minute or two remains. When the 20 minutes are up, stop the players and ask them to be seated.

PART TWO: PLAYING BINGO

Give the class the following instructions to play the game:

- When I point to you, please stand up and in a LOUD and CLEAR voice give us your name. Now, if anyone has the name of the person I call on, put a big "X" in the box with that person's name. When you get four names in a row—across, down, or diagonally—shout "Bingo!" Then I'll ask you to come up front to verify your results.
- Let's start off with you (point to a player in the group). Please stand and give us your name. (Player gives name. Let's say the player's name was "Joe.") Okay, players, if any of you have Joe's name in one of your boxes, go ahead and put an "X" through that box.
- When the first player shouts "Bingo," ask him (or her) to come to the front of the room. Ask him to give his name. Then ask him to

***Oil and Natural Gas Bingo* is a great icebreaker for a NEED workshop or conference. As a classroom activity, it also makes a great introduction to an energy unit.**

Preparation

- 5 minutes

Time

- 45 minutes

Bingos are available on several different topics. Check out these resources for more bingo options!

- Biomass Bingo—*Energy Stories and More*
- Change a Light Bingo—*Energy Conservation Contract*
- Coal Bingo—Coal guides
- Energy Bingo— *Energy Games and Icebreakers*
- Energy Efficiency Bingo—*Monitoring and Mentoring* and *Learning and Conserving*
- Hydrogen Bingo—*H_2 Educate*
- Hydropower Bingo—Hydropower guides
- Nuclear Energy Bingo—Nuclear guides
- Science of Energy Bingo—*Science of Energy* guides
- Solar Bingo—Solar guides
- Transportation Bingo—Transportation guides
- Wind Energy Bingo—Wind guides

- Now you need to verify the bingo winner's results. Ask the bingo winner to call out the first person's name on his bingo run. That player then stands and the bingo winner asks him the question which he previously answered during the 20-minute session. For example, if the statement was "can name two renewable sources of energy," the player must now name two sources. If he can answer the question correctly, the bingo winner calls out the next person's name on his bingo run. However, if he does not answer the question correctly, the bingo winner does not have bingo after all and must sit down with the rest of the players. You should continue to point to players until another person yells "Bingo."

OIL AND NATURAL GAS BINGO

ANSWERS

A. Knows the main component of natural gas

B. Can name a state that is a top 5 producer of petroleum

C. Knows what percentage of oil used in the U.S. is imported

D. Knows how natural gas is measured

E. Knows two ways to increase a car's MPG

F. Knows what percentage of U.S. electricity is generated by natural gas

G. Knows the type of rock most petroleum is found in

H. Knows two products that can be made from natural gas

I. Knows what percentage of total energy is supplied by petroleum

J. Used petroleum to get to the workshop today

K. Knows two uses of natural gas in the home

L. Knows the two types of atoms found in oil and natural gas molecules

M. Has seen crude oil

N. Knows the method refineries use to separate crude oil into useful products

O. Knows how natural gas is transported

P. Knows what OPEC stands for

A methane	**B** Texas, North Dakota, California, Alaska, Oklahoma	**C** 48%	**D** cubic feet
E proper tire inflation, regular oil change, don't keep extra weight in their car, etc.	**F** about 33% (32.6%)	**G** sedimentary	**H** fertilizer, ink, glue, paint, plastic, insect repellent, synthetic rubber, man made fabrics, etc.
I about 37% (36.6%)	**J** ask for description/details	**K** hot water heating, cooking, clothes dryer, fireplace	**L** hydrogen, carbon
M ask for description/details	**N** fractional distillation	**O** pipeline	**P** Organization of Petroleum Exporting Counties

KWL Chart

What I Think I Know	What I Want to Know	What I Learned

Forms of Energy

All forms of energy fall under two categories:

POTENTIAL

Stored energy and the energy of position (gravitational).

CHEMICAL ENERGY is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane, and coal are examples.

NUCLEAR ENERGY is the energy stored in the nucleus of an atom – the energy that holds the nucleus together. The energy in the nucleus of a uranium atom is an example.

ELASTIC ENERGY is energy stored in objects by the application of force. Compressed springs and stretched rubber bands are examples.

GRAVITATIONAL POTENTIAL ENERGY is the energy of place or position. Water in a reservoir behind a hydropower dam is an example.

KINETIC

The motion of waves, electrons, atoms, molecules, and substances.

RADIANT ENERGY is electromagnetic energy that travels in transverse waves. Solar energy is an example.

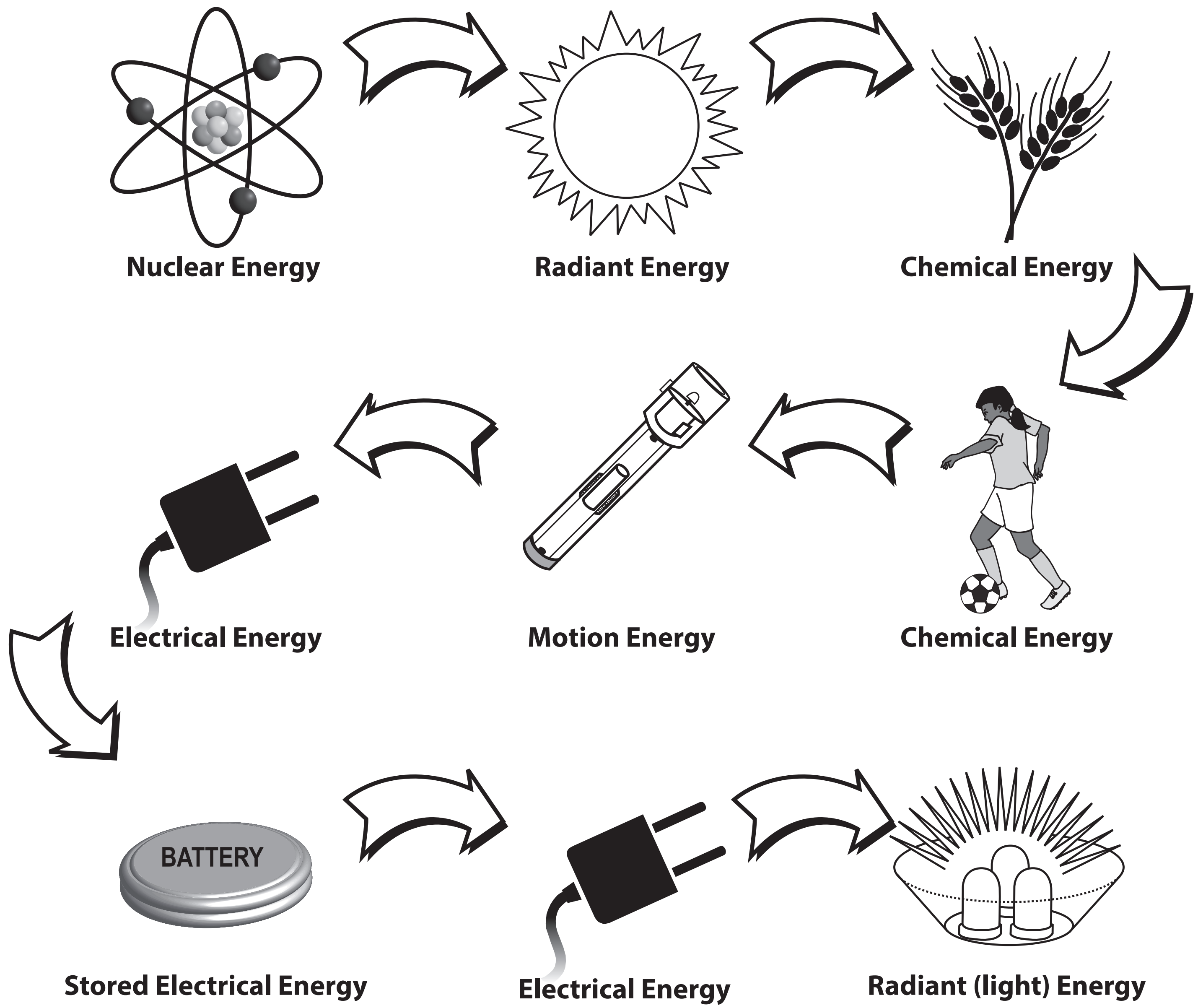
THERMAL ENERGY or heat is the internal energy in substances – the vibration or movement of atoms and molecules in substances. Geothermal is an example.

MOTION is the movement of a substance from one place to another. Wind and hydropower are examples.

SOUND is the movement of energy through substances in longitudinal waves. Echoes and music are examples.

ELECTRICAL ENERGY is the movement of electrons. Lightning and electricity are examples.

Energy Transformations
Hand Generated Flashlight



What is Energy?

Energy helps us do things. It gives us light. It warms our bodies and homes. It bakes cakes and keeps milk cold. It runs our TVs and our cars. It makes us grow and move and think. **Energy** is the power to change things. It is the ability to do work.

Energy is Light

Light is a type of energy we use all the time. We use it so we can see. We get most of our light from the sun. Using sunlight during the day instead of turning on lights saves money because sunlight is free.

At night, we must make our own light. Usually, we use **electricity** to make light. Flashlights use electricity, too. This electricity comes from batteries.

Energy is Heat

We use energy to make heat. The food we eat keeps our bodies warm. Sometimes, when we run or work hard, we get really hot. In the winter, our jackets and blankets hold in our body heat.

We use the energy stored in plants and other things to make heat. We burn wood and natural gas to cook food and warm our houses. Factories burn fuel to make the products they sell. Power plants burn coal and natural gas to make electricity.

Energy Makes Things Grow

All living things need energy to grow. Plants use light from the sun to grow. Plants change the energy from the sun into **sugar** and store it in their roots and leaves during **photosynthesis**.

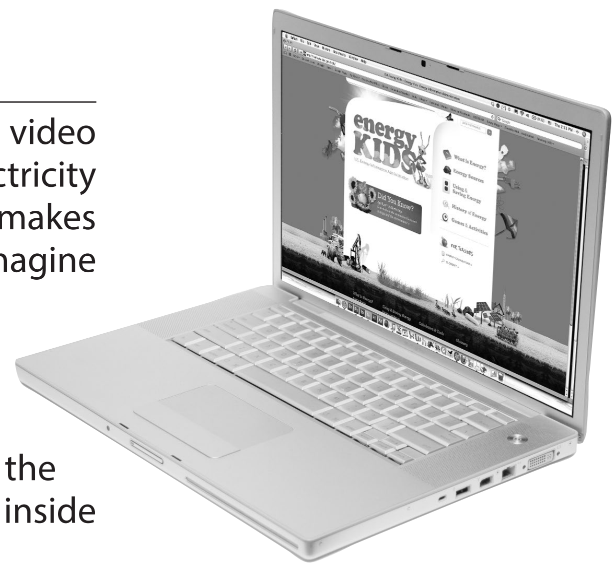
Animals can't change light energy into sugars. Animals, including people, eat plants and use the energy stored in them to grow. Animals can store the energy from plants in their bodies.

Energy Makes Things Move

It takes energy to make things move. Cars run on the energy stored in gasoline. Many toys run on the energy stored in batteries. Sailboats are pushed by the energy in the wind.

After a long day, do you ever feel too tired to move? You've run out of energy. You need to eat some food to refuel.

Energy Runs Machines



It takes energy to run our TVs, computers, and video games—energy in the form of electricity. We use electricity many times every day. It gives us light and heat, it makes things move, and it runs our toys and microwaves. Imagine what your life would be like without electricity.

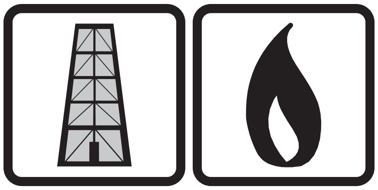
We make electricity by burning coal, oil, gas, and even trash. We make it from the energy that holds atoms together. We make it with energy from the sun, the wind, and falling water. Sometimes, we use heat from inside the Earth to make electricity.

Energy Doesn't Disappear

There is the same amount of energy today as there was when the world began. When we use energy, we don't use it up completely; we change it into other forms of energy. When we burn wood, we change its energy into heat and light. When we drive a car, we change the energy in gasoline into heat and motion.

There will always be the same amount of energy in the world, but more and more of it will be changed into heat. Most of that heat will go into the air. It will still be there, but it will be hard to use.

Photo courtesy of BP



What Are Oil And Natural Gas?

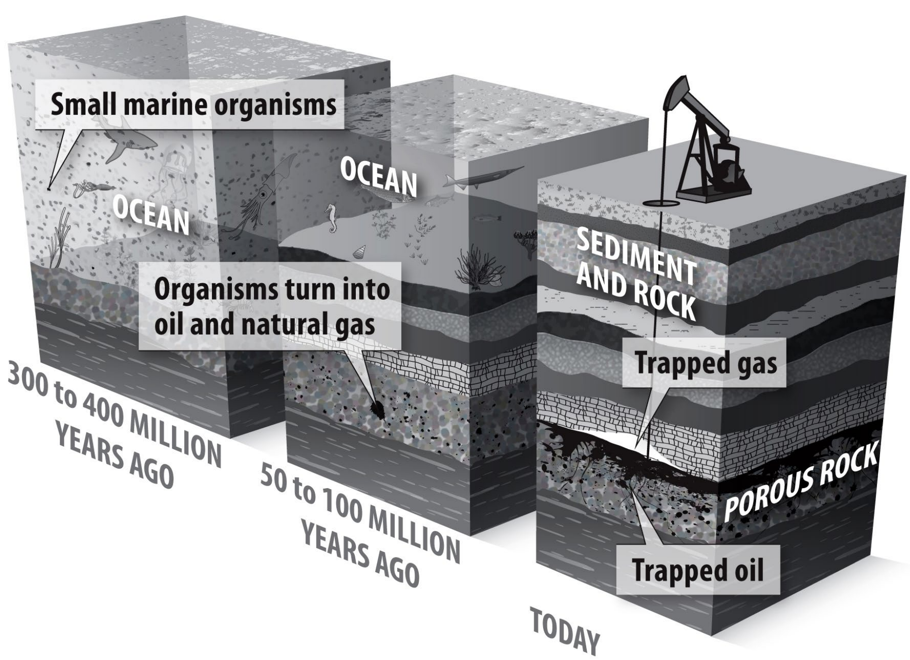
Petroleum is a liquid that is found underground. Sometimes we call it **oil**. Oil in its natural state is called **crude oil** and can be as thick and black as tar or as thin as water. Petroleum is a concentrated form of energy. One barrel of crude oil has enough energy to boil 700 gallons of water. **Natural gas** is similar to the air we breathe—it is a mixture of gases you can't see, smell, or taste. But it is very different, too; it can be very dangerous if not handled correctly. Both oil and natural gas have a lot of energy in them and can be burned to heat and power things.

How Did Oil And Natural Gas Form?

Long before the dinosaurs lived, oceans covered most of the Earth. They were filled with **microscopic** sea animals and plants. Some of the animals were **herbivores** that ate the tiny plants, other animals were **carnivores** and ate other animals, and there were **omnivores** that ate both. The **radiant energy** from the sun was stored in the plants as **chemical energy**. When the plants and the animals died, that chemical energy was stored in their remains. This happened about 300-400 million years ago.

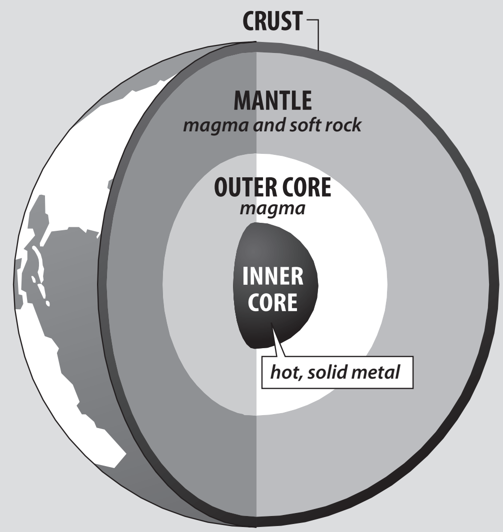
As the plants and animals died, they sank to the ocean floor. Sand and sediment covered them and turned into **sedimentary rock**. Millions of years passed. Heat from the Earth and pressure from the rock layers above turned the remains of the plants and animals into natural gas and petroleum. Natural gas and petroleum are both called **fossil fuels** because they are made from the remains of ancient plants and animals. Can you think of any other fossil fuels?

The petroleum and natural gas we use today took a very long time to form. We can't make more in a short time. That's why we call them **nonrenewable**.



The Rock Cycle

Geology is the study of rocks. **Geologists** are able to study how old each layer of rock is, what it is made of, and what useful things we can get from the rock, such as petroleum and natural gas. Geologists break all rocks into three main categories: **igneous**, **sedimentary**, and **metamorphic**.

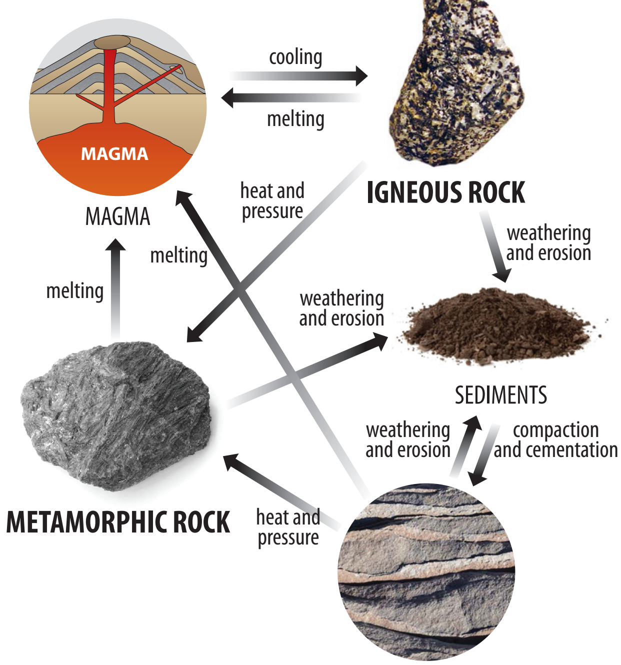


Igneous rock is formed from cooled and hardened **magma**, or **lava** — hot, liquid rock. Magma is liquid rock beneath the Earth's crust. Lava is liquid rock that is on the Earth's surface from a volcano. Magma does not only come up through volcanoes. Sometimes there are cracks, or **faults**, in the Earth's crust, and magma can seep into the spaces. Igneous rock usually has the highest **density** of the three types of rocks.

Sedimentary rock is formed by sand and **sediment** building up into layers over thousands of years. As more and more layers build on top of each other, the lower layers are compressed, or squished, and harden to become rock. This type of rock has some small holes, or **pores**, and is where most oil and natural gas are found. Some igneous rocks can have many pores like sedimentary rocks, or no pores at all. Sedimentary rocks are better for finding oil and natural gas than igneous rocks.

Metamorphic rock began as either igneous or sedimentary rock. It has been heated and compressed further until it morphs, or changes, into a new type of rock. Metamorphic rock is usually very strong and not as porous as sedimentary rock.

The Rock Cycle



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When Did People First Use Oil And Natural Gas?

Oil and natural gas have been used by many different civilizations for centuries. The ancient Egyptians collected petroleum and burned it in oil lamps. The ancient people of Greece, Persia, and India discovered natural gas many centuries ago. These people were puzzled by the burning springs that were created when natural gas seeped from cracks in the ground and were ignited by lightning. They would sometimes build temples around these never-ending flames. The ancient Chinese used natural gas as a source of thermal energy to evaporate water from seawater and collect the salt. The timeline below shows how the use and discovery of oil and natural gas have changed over the years.

Petroleum and Natural Gas Timeline

3000-2000 BCE | 625 BCE-476 AD | 1497 | 1783 | 1810 | 1820 | 1850 | 1860 | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 | 2015

Petroleum

- Ancient Chinese and Egyptians burned oil for light
- Bronze Age
- Roman Empire
- Foundation of British Empire
- United States of America wins Independence from Great Britain
- Whale oil became hard to find and a substitute was needed
- 1859 Edwin Drake struck oil and natural gas in Titusville, PA. This marked the beginning of the oil industry
- Industrial Revolution
- 1892 Development of automobile created use of previously discarded gasoline
- 1913 Henry Ford builds first moving assembly line
- 9,000,000 vehicles in the U.S. increased the demand for gasoline
- 1935 Nylon is invented. Nylon is an important product made from petroleum
- 1960 OPEC (Organization of Petroleum Exporting Countries) was founded
- 1967 First production of oil at the Alberta Tar Sands in Canada
- 1975 Strategic Petroleum Reserves were set up in response to the 1973 oil shortage
- 1977 Trans-Alaska oil pipeline is completed
- Petroleum supplies 37% of our total energy needs

Natural Gas

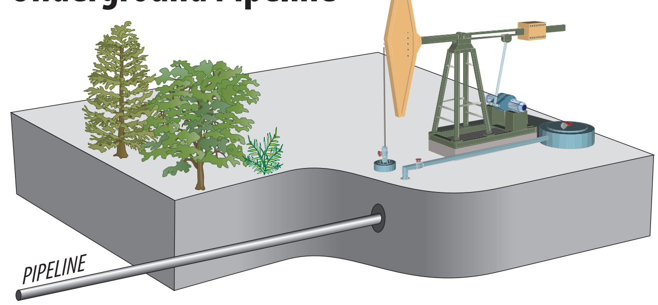
- Ancient Greeks, Persians, Indians burned seeping gas from cracks
- Approx 400 BCE Chinese piped gas from shallow wells and burned it to evaporate sea water for salt
- 1816 Baltimore streets had gas lamps
- 1820 William Hart drills the first successful gas well in Fredonia, NY, creating the Fredonia Gas Light Company
- 1859 Edwin Drake struck oil and natural gas in Titusville, PA. This marked the beginning of the natural gas industry
- 1885 Robert Bunsen invented the Bunsen burner
- 1891 A 120-mile-long pipeline was built to transport natural gas from central Indiana to Chicago, but it was not very efficient
- 1925 The first all-welded natural gas pipeline was built. It was 200 miles long and stretched from Louisiana to Texas
- 1959 The Methane Pioneer transported liquefied natural gas from Louisiana to the United Kingdom
- Natural gas supplies over 1/4 of the energy we use

How Do We Obtain Oil And Natural Gas?

Natural Gas Production

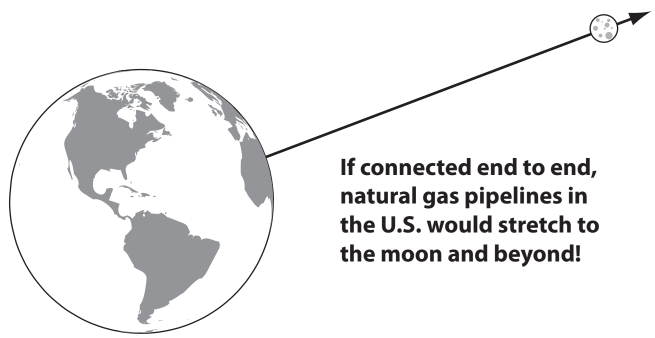
Natural gas is trapped in underground pockets of rocks much like water is trapped in the pockets of a sponge. We drill wells into the ground to reach the gas so that it can flow to the surface. This is called production. Some wells are a mile or more deep! Natural gas can be found onshore (under land) or offshore (under water and land at the bottom of the ocean).

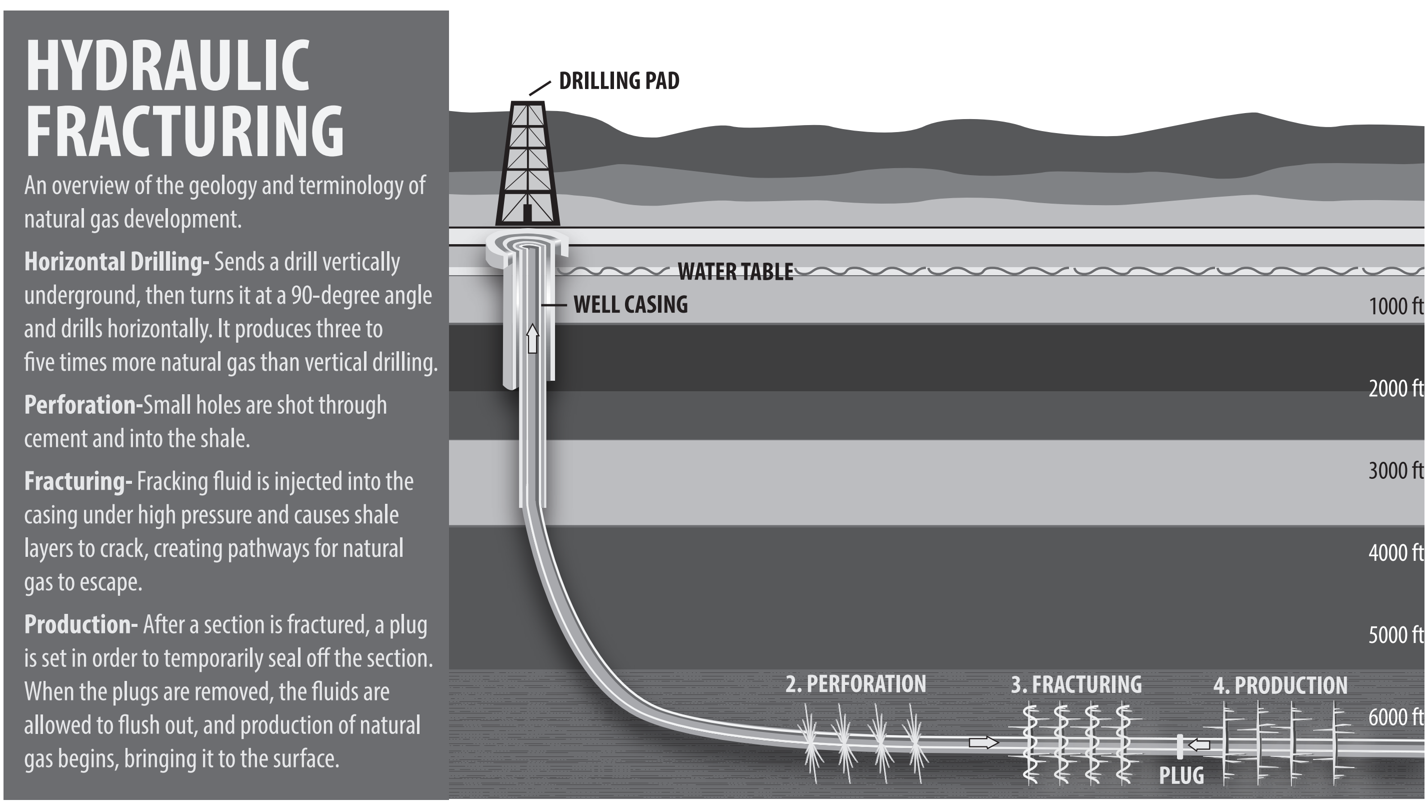
Underground Pipeline



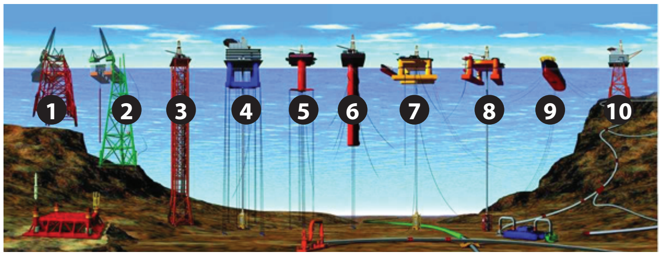
Hydraulic Fracturing

Sometimes oil and natural gas are difficult to remove from the pores of the rocks. Companies sometimes use a process called **hydraulic fracturing**, or fracking, to get it to the surface. They drill down very deep and use a liquid to break up the rock and allow the fluids to come into the well more easily.





Types of Offshore Oil and Gas Structures



Types of offshore oil and gas structures include: **1, 2) conventional fixed platforms**; **3) compliant tower; 4, 5) vertically moored tension leg leg and mini-tension leg platform; 6) spar; 7, 8) semi-submersibles; 9) floating production, storage, and offloading facility; 10) sub-sea completion and tie-back to host facility**

Image Courtesy of NOAA

Natural gas is a mixture of gases. The natural gas is piped from the wells to machines that clean it and remove any water. The main ingredient in natural gas is **methane**. Methane has no color, odor, or taste. As a safety measure, gas companies add an **odorant** to the gas, called **mercaptan**. It smells like rotten eggs, so that leaks can be detected.

We move natural gas from one place to another in **pipelines**. There are almost two million miles of pipeline all across the United States moving natural gas from wells to processing plants to our homes, factories, and buildings.

OIL TANKER

Image Courtesy of BP

Oil Production

Petroleum is buried underground in tiny pockets in rocks. We drill oil wells into the rocks to pump out the oil. Sir Edwin Drake drilled the first oil well near Titusville, PA in 1859. His well was only 69 feet deep when he struck oil. The typical well today is about one mile deep (5,280 feet). Texas and Alaska are the states that produce the most oil.

A lot of oil is under the oceans along our shores. Oil rigs that can float are used to reach this oil. Most of these wells are in the Gulf of Mexico.

OIL DERRICK

PIPELINES

After the oil is pumped to the surface, it is shipped from one place to another through pipelines and by ships and trucks to special processing plants called **refineries**. The United States doesn't produce enough oil to meet our needs. We import a little less than half of the oil we use from other countries.

Technology and the Petroleum and Natural Gas Industries

Current drilling methods are more accurate because of the advancement of technology. Computers and other advanced technology are used by the petroleum and natural gas industries to greatly improve production, and reduce cost and environmental impact.

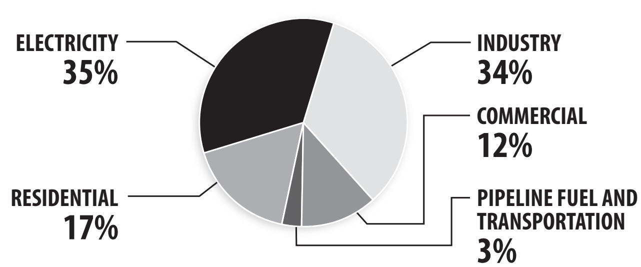
Horizontal drilling provides a means by which oil and gas producing companies can reduce the number of wells they must drill. This drilling allows them to drill in many directions from a single **vertical** well. The amount of land needed for horizontal wells is much smaller because the number of wells needed is reduced.

An engineer in one location can operate a drill in a location half way around the world and with amazing accuracy, thanks to computers. Due to better technology in exploring for petroleum, the cost of production is reduced by millions of dollars as fewer wells are mistakenly drilled in places where there is no oil.

We Use Natural Gas Every Day

Almost everyone in the United States uses natural gas. **Industry** is the biggest user. Factories burn natural gas for thermal energy needed to manufacture products like paper and cement. Natural gas is also an ingredient in paints, glues, fertilizers, plastics, medicines, and many other products.

U.S. Natural Gas Consumption by Sector, 2015



Data: Energy Information Administration
*Data does not add to 100% due to independent rounding.

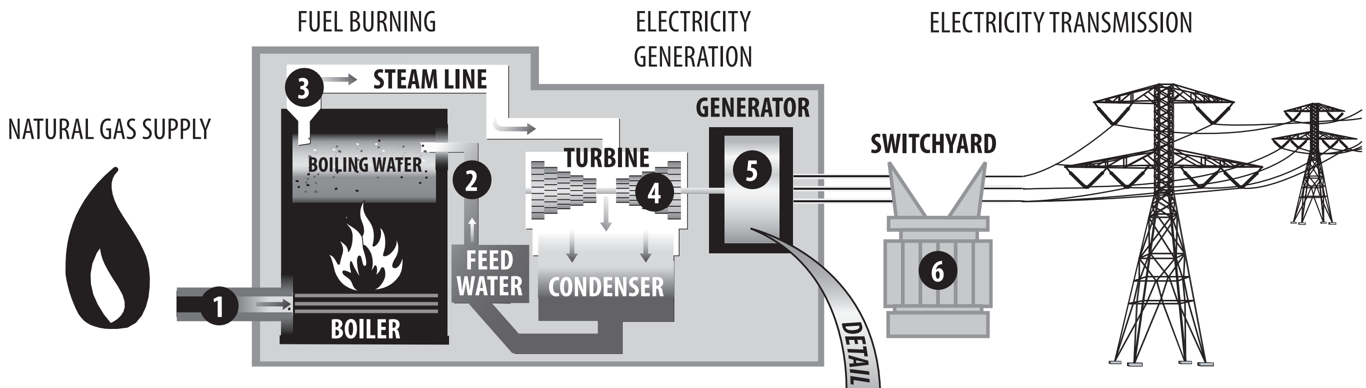
Residences, or homes, are the second biggest users of natural gas. More than half of the homes in the United States use natural gas for heating, and many also use it for cooking and heating water.

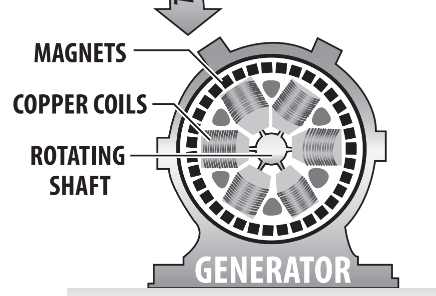
Commercial buildings use natural gas too. Commercial users include schools, stores, offices, churches, and hospitals. These buildings use natural gas in the same ways as residential buildings do.

Natural gas is a major source used to generate electricity. Many power companies have power plants that burn natural gas to make electricity. Natural gas plants can produce electricity quickly when needed. Natural gas burns more cleanly than coal.

Natural gas can also be a cleaner burning **transportation** fuel when **compressed** (put under pressure). Natural gas vehicles burn so cleanly that they are used to carry TV cameras and reporters ahead of the runners in marathons.

Natural Gas to Electricity





1. Natural gas is fed into a boiler via a pipeline. It is burned to release thermal energy.

2. Water is piped into the boiler and heated by the thermal energy released, turning it into steam.

3. The steam travels at high pressure through a steam line.

4. The high pressure steam turns a turbine, which spins a shaft.

5. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.

6. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.

CNG—Compressed Natural Gas

Natural gas is an energy-rich fossil fuel. It burns cleaner than gasoline, making it a good fuel source for the future. Natural gas is also less expensive than gasoline. Natural gas is compressed into tanks to use in vehicles. Even under pressure, it only has about one-third as much energy as gasoline. Vehicles that run on natural gas have a shorter range than gasoline-fueled cars. Range is the distance a vehicle can go on one tank of fuel. If more tanks are added to increase the amount of fuel, the vehicle gets too heavy. Extra fuel tanks also take away space for storage and passengers. Some people worry about using CNG because natural gas is **flammable**. CNG tanks are stronger than tanks designed to hold gasoline. CNG tanks are more difficult to damage in crashes than gasoline tanks. Even if a fuel line breaks, there is less danger because natural gas is less dense than air, and rises when released. Compare this to gasoline, which, as a liquid, forms puddles on the ground that can catch on fire where people are. Also, natural gas catches fire at a much higher temperature than gasoline, which means more energy is required to **ignite** natural gas than gasoline. This makes natural gas safer than petroleum.

Today, there are nearly 1,000 public and private natural gas fueling stations in the United States—much fewer than the one hundred thousand gasoline stations. If we are going to use natural gas in more vehicles for businesses, we will need many more fueling stations so people can refuel their vehicles. Natural gas vehicles are good as fleet vehicles for businesses with their own fueling stations. Many businesses with CNG fleets say their vehicles last longer because the fuel is so clean burning.

BUS FUELED BY NATURAL GAS

Image courtesy of Environmental Protection Agency

Some city buses are fueled by natural gas.

Liquefied Natural Gas (LNG)

Most natural gas is transported from place to place by pipeline. But what happens if an area needs natural gas but does not have a pipeline going to it? What should a country that has more natural gas than it needs do with the extra? It would be difficult to transport a gas long distances.

LNG TANKER

LNG is transported overseas by ship. Many of these ships have a membrane hull design.

Natural gas can easily be transported over long distances if the gas is cooled to a liquid. As a liquid, natural gas takes up much less space and more can be transported. The process of cooling a gas to a liquid is called **liquefaction**. Natural gas must be cooled to -260 degrees Fahrenheit to turn it into a liquid. As you can imagine, that's very, very cold, colder than the coldest place on Earth! However, once it is in liquid form, natural gas can be loaded into trucks or ocean tankers and shipped overseas. Moving LNG is easier, too, because the same weight of LNG is 600 times smaller in volume as gaseous natural gas.

LNG must be brought into a LNG terminal. There it is stored in very large, insulated tanks until it is ready for use. Then it must be changed back into a gas from a liquid. This process is called **regasification**. After they allow it to warm and become a gas, it is sent into a pipeline for transport to local users. The tanks have an outer wall and an inner wall, and a layer of insulation, much like your home has, that keeps the LNG cold. Sometimes LNG is also pumped and stored underground in salt caverns.

We Use Petroleum Every Day

The first crude oil was refined only into kerosene for use in kerosene lamps for lighting. At that time, the rest of the product was tossed away. In 1913, Henry Ford began producing automobiles more quickly. This made automobiles more available to lots of people. Because automobiles use gasoline, the need for gasoline greatly increased. Today, our country would come to a stop without fuels made from petroleum. Most of our cars, trucks, ships, and planes are powered by petroleum products. We depend on petroleum fuels to travel from place to place and to bring us food and other items that we need in our daily lives.

Getting The Gasoline Out—And Other Products, Too

When oil arrives at a refinery, it is separated into its many different **compounds**. Refineries use a process called **fractional distillation** to separate the materials. This process sorts the compounds by their boiling point, or the temperature at which the compound boils or bubbles. The different compound groups are then transported for more refining, processing into transportation fuels, or to be made into products such as plastic.

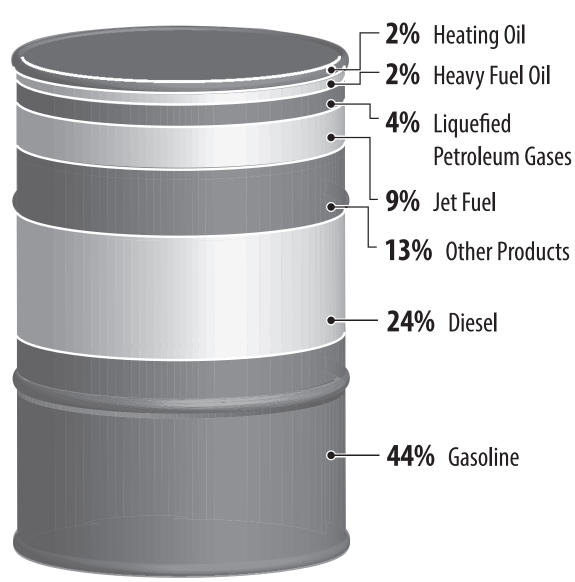
Oil is measured in barrels; one barrel is approximately 42 gallons. The United States uses more than 19 million barrels of oil each day. About 44% of oil is processed into gasoline (20 gallons of finished product from each barrel).

GAS STATION

Image courtesy of Environmental Protection Agency
Petroleum is the energy source from which we get gasoline.

OIL REFINERY

Products Produced From a Barrel of Oil, 2015



*Total does not equal 100% due to independent rounding.
Data: Energy Information Administration

Not Just For Transportation

Our factories use oil to make plastics and paints, medicines and soaps. Did you ever think about your action figures, your CDs, or even lipstick being made from petroleum? We also burn oil to make electricity that runs our lights and appliances. We use more petroleum than any other energy source.

Petroleum, Natural Gas, and the Environment

Petroleum keeps our world moving. Many of the petroleum and natural gas products, such as medicines and fertilizers, have helped people throughout the world. There are some risks to using petroleum and natural gas, especially if they are not handled properly. Burning gasoline and other fuels in vehicles can pollute the air and become a problem in many parts of the country. Burning these fuels also releases carbon dioxide, a gas that is linked to climate change. However, oil companies work very hard to try to protect the environment. Gasoline and diesel fuel have been processed to burn cleaner and oil companies do everything they can to drill, process, and transport oil and its products as safely as possible.

Oil companies work hard to drill and transport oil and natural gas as safely as possible, but sometimes spills do occur and cause damage to the land and wildlife in the area. Oil spills are cleaned up as quickly as possible to restore the **habitat** to its natural state.

Products Made From Petroleum

Petroleum fuels can contribute to air pollution.

Natural gas must be burned like gasoline. However, natural gas burns much cleaner and releases less pollution than most fossil fuels.

Exploring Density

Background

Density is a physical property that tells us how much space a substance will occupy. For example, water has a density of 1.00 g/mL, which means one gram of water will take up a volume of one milliliter. Objects that float in water have a lower density than water, and objects that sink have a higher density than water.

The density of rocks is important to geologists when they are looking for oil and natural gas deposits. Rocks lower in density are more likely to hold oil or gas deposits because they are also often porous.

Question

Do all items have the same densities?

Hypothesis

Materials

- Graduated cylinder
- 600 mL Beaker
- Corn syrup
- Water
- Vegetable oil
- Plastic button
- Grape or blueberry
- Small cork
- Penny
- Glass marble
- Wooden bead or wooden button
- Ice cube

✔ Procedure

1. Predict what you think will happen when you pour the three equal amounts of liquids into the containers. Illustrate and explain your prediction.
2. Pour the oil into your container. After it settles, pour in an equal amount of water. Finally, pour an equal amount of corn syrup into the beaker.
3. Let the liquids settle for a few minutes. Observe and record in your science notebook what happens.
4. Predict what you think will happen when you drop each object separately into the container with the three liquids. Use your data table to record predictions.
5. One at a time, gently drop each object into the container.

6. Observe where the objects settle and record the results in your data table.
7. Draw a diagram of your container. Make sure to color each liquid a different color and to illustrate where each item you dropped into the container is located in the container. Label each item.

Data and Observations

Use the chart to record your predictions and observations:

Object or Liquid	Predicted Position (Bottom, Middle, Top)	Observed Position (1-10) (From Bottom to Top)
Cork		
Corn Syrup		
Glass Marble		
Grape		
Ice Cube		
Oil		
Penny		
Plastic Button		
Water		
Wooden Bead or Button		

Conclusions

1. Rank the objects in order from least dense to most dense.
2. How do you know you have correctly ranked the order of densities? What about your experiment told you that was the answer?
3. How can scientists and engineers searching for oil or natural gas use density to help them find good places to drill a well?

Extension

- With your teacher's permission, predict and test the density of other items you are curious about. Record their information.

Exploring Porosity

Background

A pore is a small hole in something. Many things have pores. Sometimes the pores are so small they can only been seen with a microscope, and sometimes they are large enough to be easily seen. Sponges have pores. They're really big, and are what allow a sponge to hold water. The water flows through the sponge, filling up the pores. Not all pores are big though. Rocks have pores, and sometimes they're very small. Limestone and shale are two common sedimentary rocks. They can both hold water, oil, or natural gas because they have lots of pores. Geologists look for rocks with lots of pores when looking for oil and natural gas.

Question

How does the porosity of a rock affect its ability to hold liquid or gas?

Hypothesis

Materials

- 3 Beakers
- Water
- 100 mL Graduated cylinder
- Large objects such as coarse gravel or extra-large marbles
- Medium objects such as pea gravel or marbles
- Small objects such as aquarium gravel or tiny beads

Procedure

1. Label your beakers with the numbers 1, 2, and 3.
2. Fill beaker 1 to where your teacher tells you to with the large objects.
3. Fill beaker 2 to the same height as beaker 1 with the medium-sized objects.
4. Fill beaker 3 to the same height as beaker 1 with the small objects.
5. Predict which beaker will hold the most water to the fill line. Which will hold the second most? Which will hold the least? In your data table, label your prediction for the beaker that holds the most as number 1. Label the beaker that you think holds the least as number 3.
6. Measure 100 mL of water in your graduated cylinder. Pour water into beaker 1 until you reach the the top of the rocks. Add more water and keep filling even if you have not yet reached the top of the materials. Subtract the water that is left in the cylinder from 100 and record the "volume of water added" in the data table.
7. Fill the cylinder back to the 100 mL line with water.

8. Repeat steps 6 and 7 for beakers 2 and 3 and record the volume of water used in the data table.
9. Look at the volumes of water recorded in the data table. The most porous rock holds the most water.
10. Using your data, re-rank the beakers 1-3 according to the amount of water you were able to add to the beakers.
11. Looking at the volume of water each beaker could hold, and recalling the information you read in the background and student text, determine whether each beaker best models an igneous, sedimentary, or metamorphic rock. Write I, S, or M in the box on the data table.

Data and Observations

Use the chart below to record your predictions and observations:

Rock (each beaker represents a different rock)	Prediction of Porosity	Volume of Water Added	Actual Porosity	Igneous, Sedimentary, or Metamorphic
Rock One (Filled with large substances)				
Rock Two (Filled with medium substances)				
Rock Three (Filled with small substances)				

Conclusions

1. Which type of rock are most petroleum and natural gas deposits found in? Explain why.

2. Explain the relationship between porosity and finding petroleum and natural gas.

3. If we had used rocks (beakers) that you could not see through, how could you determine the density or porosity of rocks?

Formation of Petroleum and Natural Gas Listening Activity

Question

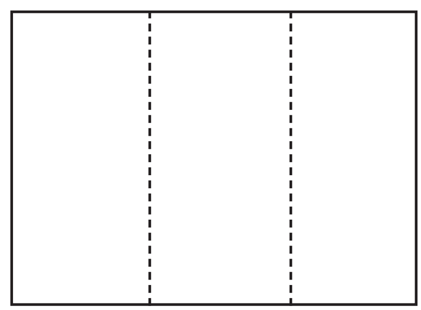
How are petroleum and natural gas formed?

Materials

- 8 ½" x 11" Sheets of paper
- Colored pencils and markers

Procedure

1. Your teacher will give you a piece of paper. If it is not already divided and labeled, fold it into three sections of equal size, as shown below. Label the three sections Scene 1, Scene 2, and Scene 3.
2. Your teacher is going to read a story twice. The first time the story is read, just listen carefully. Try to picture each scene in your mind as your teacher reads.
3. The second time your teacher reads the story, illustrate what your teacher is saying. Your teacher will pause frequently to allow you time to draw.
4. At the bottom of the first scene, write "300 to 400 million years ago."
5. At the bottom of the second scene, write "50 to 100 million years ago."
6. At the bottom of the third scene, write "Today."
7. After the story is finished, color your illustrations.



Teacher Script

1. **Scene One**—300 to 400 million years ago, a large sea covered the area we now recognize as the southern part of the United States. In this sea lived a large number of microscopic plants and animals called plankton. When the plants and animals died they were buried on the ocean floor and then covered with layers of sediment and rock.

2. **Scene Two**—50 to 100 million years ago the remains of the microscopic plants and animals were buried deeper and deeper. Enormous heat and pressure turned them into petroleum and natural gas.

3. **Scene Three**—Today we drill through the layers of sedimentary rock to reach the rock formations that contain oil and natural gas deposits.

Illustrating Stories

Question

How can younger students learn about oil and natural gas?

Materials

- Construction paper
- Poster board or material for cover
- Markers or crayons
- Binding material from your teacher
- Copy of a story to illustrate

Procedure

1. Your teacher will assign you to work with a group of classmates, and will give you a copy of an energy story. You will illustrate and create a book to share with other students.
2. Read the story individually.
3. As a group, decide who will take each of the following roles. People may have more than one role.
   - One person who gets supplies
   - One person who records ideas from your group
   - One person who organizes the story
   - Several people to draw pictures
   - One or two people who have neat handwriting to copy the story into your booklet
4. As a group, decide how you will illustrate the story. Decide if it will be similar to a traditional story book, like a comic book, or some other format you choose.
5. Within your group, brainstorm ideas for illustrations for the different parts of the story. Write down all ideas.
6. Look at your list of ideas and as a group decide which are the best.
7. Divide the work evenly among all group members and illustrate your story. Be sure to write the appropriate part of the story below each illustration.
8. When your story is finished, make a cover for the booklet.
9. Bring your booklet to your teacher and get help binding it together with the materials your teacher has chosen, such as staples or yarn.

Under the Sea

Hi, there! I'm Sue Ann. I'm a teeny, tiny sea animal.

At least, I used to be.

That was a long time ago—hundreds of millions of years ago.

Meet my friend Zeke. He was once a sea plant.

After all those years, I bet you're surprised we're still around.

We've seen dinosaurs come and go. And cave dwellers.

We've seen ice ages and floods and earthquakes.

We've watched the Earth go through a lot of changes.

Can you see us buried in the rocks under the water?

I guess you don't recognize us.

We've gone through a lot of changes, too.

I don't look like a sea animal any more. And Zeke isn't green.

When we died, we sank to the bottom of the sea.

We got buried under the sand with other plants and animals.

They all piled on top of us.

Do you know how it feels when you get stuck under a huge pile of covers?

You get hot and squished, right?

That's what happened to us.

We were trapped under all that stuff.

After a few million years, the pile on top of us turned to rock.

It got heavier and heavier and we got hotter and hotter.

Finally, I think we sort of melted.

That's what it felt like anyway.

We turned into a pool of sticky oil with a gas bubble on top.

Can you see us yet? Look hard!

We're trapped in a little pocket of rock.

One of these days, they'll send out a search party for us.

They'll study maps and bounce sound waves off the rocks.

They'll drill a hole down through the rocks and find us.

They'll pump us up to the surface—the oil and the gas.

They'll clean us up and turn us into all kinds of things.

I can't wait to see what happens to me.

Maybe I'll be natural gas and travel in a pipeline to your house.

I'd keep you warm and cook your dinner.

Maybe I'll be a fancy plastic toy to make your baby brother laugh.

Or the stuffing in your sleeping bag.

Maybe I'll be the medicine that helps you feel better the next time you get sick.

Perhaps I'll be the crayons you use to color a picture.

Or the ballpoint pen you use to write your name.

Maybe I'll be gasoline and take you to school.

Or jet fuel and fly the President around.

Maybe I'll be propane and cook your hot dogs on the grill.

There are so many things I might be. It's so exciting to think about!

Into Deep Water: Drilling for Oil and Natural Gas

Stacey has trouble falling asleep. She's so excited. Tomorrow is a very special day for all the kids at school. They are going to work with their parents.

Her friend, Susie, is helping her mom at the bakery. Her friend, Tanya, is going to the office with her dad. Stacey is going to work with her dad, too. But not to an office!

Stacey's going out into the Gulf of Mexico on a boat. Her dad works on an oil rig. He looks for oil buried deep in the rocks under the water.

Before daylight, her dad wakes her. They drive to the dock in the early morning darkness. A crew boat is waiting. Stacey and her dad jump onto the boat. Other people climb aboard carrying suitcases.

"Dad," asks Stacey, "are all these people going to stay on the rig for three weeks like you do?"

"Most of them will. But not us. We'll ride back this evening with the workers going home."

The crew boat takes off and Stacey watches the sun rise over the water. It's a beautiful sight. The workers tell her stories about life on the rig, watching movies and playing cards. Last year, Stacey had Thanksgiving a week late because her dad was working.

"How deep is the water?" she asks. "All I see is water everywhere I look."

"Under the rig, the water is about 300 feet deep. It's a shallow rig. Some rigs are in water almost a mile deep. Those are called floating rigs and they're tied to the bottom by big cables."

Suddenly, her dad points to a tower on the horizon. "There she is, Stacey. There's my office."

At first, the rig looks tiny. It grows and grows as they get closer.

"Dad, how did you build the rig way out here?" Stacey wants to know.

Her dad laughs. "We didn't build it out here, Stacey. We built it on shore, then towed it out here on a big barge. It took almost a year to build."

The crew boat pulls up to the rig. A big basket drops down from the deck above them.

"Jump into the basket, Stacey," says her dad, giving her a hand, "and hold on tight. The air tugger lifts us up fast."

"Is this the only way to get up there, Dad?"

"Yep, this is the only way when you come by boat. The helicopters can land right on the deck. I hope the tugger operator is in a good mood today. Sometimes he dips new people into the water before he lifts them up."

"Dad, he won't do that, will he? I didn't bring extra clothes!"

"Don't worry, Stacey, we've got a laundry room on the rig."

Stacey holds on as the basket sways in the wind. The ride up takes only a minute. They climb out of the basket onto the deck. Ladders and machines are everywhere. The drilling unit towers above her.

"Let's go see the kitchen first, Stacey," says her dad. "I'm hungry."

"Me, too!" answers Stacey. "I didn't get any breakfast." They climb down a ladder to a lower deck.

Stacey can't wait to eat on the rig. Her dad has told her about the food—four meals a day. She'd eat macaroni and cheese at every meal.

After they eat, her dad shows her the bunk room where he sleeps. There are bunks for four people in the room.

He shows her the recreation room where the workers play pool and watch movies. He shows her the laundry room and the bathroom and the showers.

"Dad, where does the waste go? You don't dump it in the water, do you?"

"Oh, no, we'd never do that. It all goes into a big tank and a boat takes it to shore. Some of the really big rigs have their own waste treatment plants."

Her dad grabs her hand and pulls her up a ladder. "We've got a neat machine up here. It takes the salt out of the sea water. It makes clean water for us to use, so we don't have to ship it from shore."

"This is just like a city out here," says Stacey. "You've got everything."

"Well, not everything. I hate not being able to call you every day when I'm gone so long."

"I know," answers Stacey, "but, when you do come home, you're home for three weeks. Now show me how you drill for oil. That's what I really want to see!"

Stacey and her dad climb back up to the rig deck. He shows her a map of the sea floor under the rig. There are twenty X's on the map. They plan to drill a well on each X to look for oil.

Stacey's dad shows her the pipes where the drills go down into the water. He shows her the machines that run the drills. He shows her the X where they are drilling today.

"What happens when you find oil, Dad?" asks Stacey.

"We pump it out of the rock into a pipe. Then an oil tanker takes it to a refinery on shore."

"Doesn't any of the oil leak into the water?"

"We're very careful, Stacey. We know that oil can pollute the water and hurt the fish and plants. We do everything we can to keep any oil from leaking into the water. Let me show you what I do."

Her dad leads Stacey into a room filled with lots of control panels.

"Wow, Dad! This is where you work? It's so cool!"

"This is it. I use these control panels to run the wells. I make sure the oil and gas don't come out too fast. I'm called a blow-out specialist."

"A blow-out specialist. I like that. What's next?"

"Let's swing by the kitchen and grab a snack. Then I want to take you back up on deck. I've got one more thing to show you."

"Sounds good to me, Dad. I'm getting hungry."

Stacey and Dad have a snack and climb up to the deck. They walk to the railing. Way down below, Stacey sees two people fishing.

"I've caught some great fish down there, Stacey," says her dad.

Stacey smiles. "I'm glad you take care of the water, Dad. You know how important that is to me."

Suddenly her smile turns into a frown. "What do you do when a storm comes? Couldn't that make the oil spill?"

“Storms can be dangerous, Stacey. The first thing we do is shut the wells and stop drilling. Then, if the storm looks bad, we send most of the workers to shore. Only a few people stay on the rig.”

“You always stay, don’t you, Dad?”

“It’s part of my job.”

“Do you ever get scared?”

“Excited maybe, but not really scared. I would leave if I thought there was a real danger. Don’t worry.”

All of a sudden, a siren begins to blow. Stacey jumps. “What’s that, Dad? Is something wrong?”

Not a thing, Stacey. That’s the siren to let us know the crew boat is about to leave for shore. Anybody who misses the boat will have to stay on the rig for two days, until the next crew boat comes.”

“Let’s miss it, Dad. I love it out here. I want to work on a rig, too. Maybe I’ll be a blow-out specialist, just like you.”

“You can be anything you want to be, Stacey, when you grow up. But right now, we’re getting back into the basket.”

Stacey and her dad climb in and wave good-bye to the crew. As they near the boat, the operator dips the basket into the water.

Stacey shakes her fist at him and laughs. As the crew boat heads into the sunset, Stacey’s hand slips into her father’s. It has been a perfect day, even if her feet are wet.

Let´s Take Core Samples

Background

How do petroleum geologists find oil and natural gas deposits? How can they tell where the right kind of rock is located, since they can't see through the ground? While they can't see what kind of rocks are there, or where they are, they can use a variety of techniques to find sedimentary rock. One method they commonly use is to take core samples. A long, hollow drill, called a core drill, is pushed into the ground and removed. Inside the drill is a long cylinder of rock, with the layers arranged exactly as they are in the ground. Geologists then use the thickness and depth of the different kinds of rock they see in the core to help determine where oil and natural gas are most likely to be found. They call the arrangement of the layers of rock stratigraphy.

Question

What is it like to drill for oil and natural gas?

Hypothesis

Materials

- One cupcake provided by your teacher
- Three straw halves
- Plastic knife

Procedure

1. Your teacher will give you a cupcake. This represents the part of land or water in which you are going to explore for oil or natural gas.
2. Listen as your teacher explains what the different colors inside your cupcake represent.
3. Push one of the straw halves into your cupcake and pull it out. This is your first core sample.
4. Make a diagram of your first core sample in the data table. Label it with the correct types of rock.
5. Make a prediction about where you are most likely to find sedimentary rock in your cupcake using your core sample.
6. Take a second core sample in the area you predicted. Make a diagram in your data table.
7. Use the information from core sample #1 and core sample #2 to determine where you will drill for oil.

8. Use the third straw to drill your "well." As before, diagram your core sample.
9. If your third core sample has a large amount of sedimentary rock, you have successfully located an oil or gas deposit and will have a productive well.
10. Use the plastic knife to cut your cupcake in half. Compare the cupcake with the diagrams you made, and your predictions.

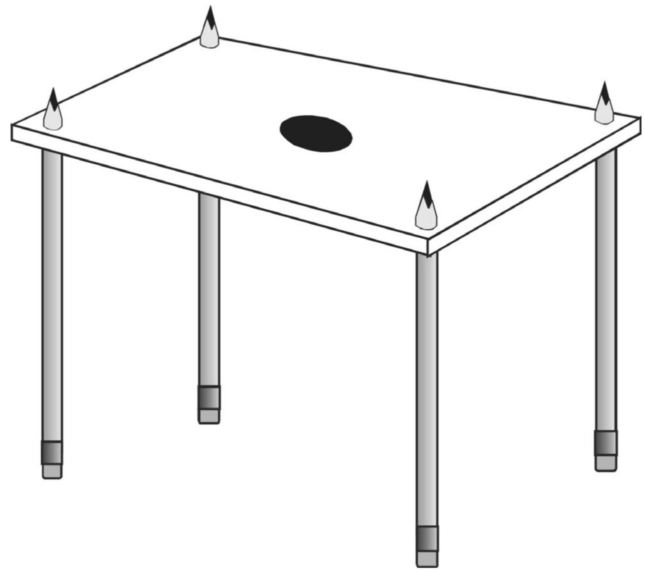
Data and Observations

Use the chart below to record your predictions and observations:

- Red represents igneous rock
- Blue represents metamorphic rock
- Yellow or white represents sedimentary rock

First Core Sample	Core Sample 1 Diagram	Prediction of stratigraphy of cupcake
Second Core Sample	Core Sample 2 Diagram	New prediction of stratigraphy of cupcake
Drilling for Oil—Third Core Sample	Draw the third core sample that represents where you chose to put your well.	Draw your prediction of the stratigraphy of the cupcake after 3 drillings.
Did you strike oil or gas?	Why did you choose where you chose to drill your final well?	Draw the cupcake stratigraphy after you have cut the cupcake in half.

Drilling for Oil in the Ocean



Question

How do scientists drill for oil in the ocean without getting wet?

Hypothesis

Materials

- Foam platform
- 2 Clear plastic straws
- Aquarium with sand and water inside
- Clear tape

Procedure

1. Tape two straws together end to end so that the juncture is completely sealed to make a drill.
2. Try to strike oil. Insert your drill through the hole in the deck into the sand until it hits the bottom of the aquarium. Cover the end of the straw tightly with one finger and remove the straw.

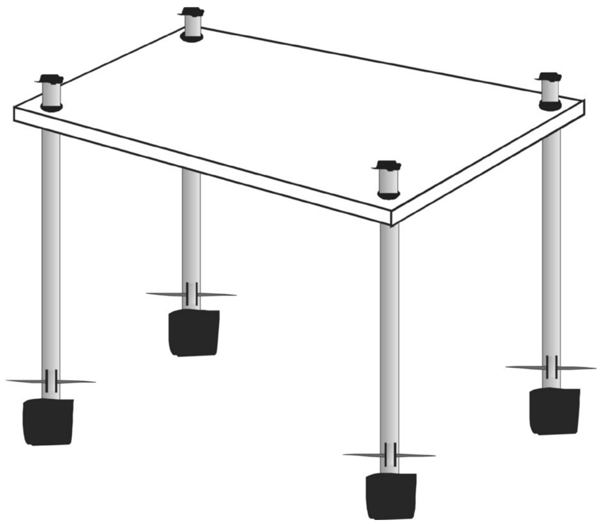
Conclusion

Is there any dark sand in the end of the straw? Did you strike oil? How many times did you drill before you found oil?

Research Questions

1. How do geologists determine where to look for oil under the ocean?
2. What are the challenges of finding and producing oil from offshore basins?
3. What would life be like working on an offshore oil rig?

Build a Stationary Oil Rig



Background

An oil rig is built on shore, then floated out to the drilling site on huge barges. In shallow water, a rig rests on the ocean floor on long, hollow legs. While the rig is being towed to the site, the legs are filled with air. Once the rig reaches the site, valves in the legs are opened and the legs slowly fill with water, so that they sink to the bottom.

Question

How does an oil rig stay in place in the ocean?

Hypothesis

Materials

- Aquarium with water
- Foam platform
- 4 Clear plastic straws
- 4 Toothpicks
- Sharp scissors
- Clay

Procedure

1. The slits your teacher cut in the straws will act as water valves.
2. Make holes at the corners of the foam board and insert the ends of the straws without the slits.
3. Seal both ends of the straws with clay. Mold the clay on the bottoms into feet that are each 2 cm x 2 cm square.
4. Float the platform in the aquarium.
5. Insert toothpicks in the slits in the straws to hold them open (opening the valves in the legs of the rig).
6. Break the seal of the clay at the top of the straws so that the air in the straws can escape.

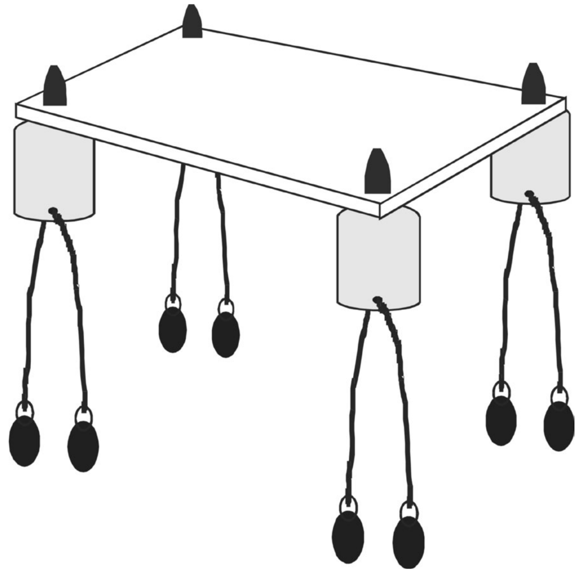
Conclusion

Describe the action of the rig as the straws filled with water.

Research Question

1. What is the maximum depth of water in which a stationary rig could be used?

Floating Oil Rig



Background

When drilling in deep water, a floating rig is used. Air-filled tanks (called ballast tanks) support the rig, which is secured to the bottom of the ocean.

Question

How are oil rigs placed in very deep water?

Hypothesis

___

___

___

Materials

- Aquarium with water
- Foam platform
- 4 Small empty glue bottles with twist-close tops
- 4 Pieces of string or yarn 45 cm long
- 8 Small weights such as sinkers
- Sharp scissors

Procedure

1. Run a piece of string through the holes in the glue bottles so that the string is hanging evenly from each bottle.
2. Attach the weights to the ends of string.
3. Remove the tops from the glue bottles.
4. Make holes in the foam board big enough for the necks of the glue bottles. Insert the bottles through the holes and replace the tops, closing them tightly.
5. Place the rig in the aquarium.
6. Spread out the weights on the bottom of the aquarium to secure the rig.
7. Open the tops of the glue bottles.

Conclusion

What happened when the tops of the glue bottles were opened?

Research Questions

1. As more equipment is added to a floating rig, would you want more or less air in the ballast tanks?
2. What are some unique challenges to drilling in deep water?

Perforated Well Casing

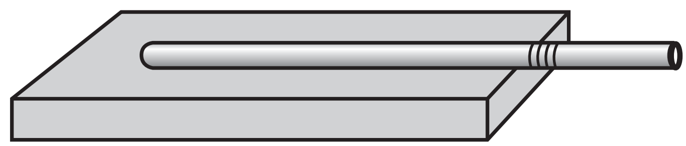
Question

How do you think adding holes to a well casing will change the amount of petroleum or natural gas that a well can produce?

Hypothesis

Materials

- Two kitchen sponges, the same size and shape
- Flexible straws
- Push pin
- Shallow tray (for sponges)
- Shallow tray (for collection from straw)
- Plastic wrap
- 1-3 Heavy books or weights
- 10-20 mL Graduated cylinder
- Water
- Tape
- Paper towels



✔ Procedure

1. Lay plastic wrap out across your shallow tray. Place one sponge on top of the plastic wrap.
2. Lay a straw on the sponge so the bottom edge of the straw is inside the end of the sponge and the elbow end of the straw stretches out beyond the edge of the sponge. If necessary, trim the bottom end of the straw so the end of it is inside the end of the sponge by at least 3 cm (see diagram).
3. Lay the second sponge on top of the straw/sponge combination so the edges align with the first sponge.
4. Pour water on the sponges so they are saturated but almost no water is leaking out. Record how much water you used.
5. Wrap the plastic wrap around the sponges and up around the straw, trying to create a sealed set-up with no places for water to leak out. Use tape if necessary to help create a seal. Make notes of your assembly so you can repeat the set-up again.
6. Place the other shallow dish beneath the end of the straw protruding from the sponges.
7. Gently lay a heavy book on top of the sponges and observe the amount of water that comes from the straw.

8. Add another book to the first, and continue until no water comes from the straw. Try using your arms to provide more pressure, if needed.
9. Record observations. Measure the amount of water in the collecting dish by pouring it into the graduated cylinder.
10. Disassemble the stack of books, sponges, and straw. Drain or squeeze your sponges to remove as much remaining water as possible.
11. Using a push pin, poke several holes about 3-5 mm apart on both sides of the end of the straw that was between the sponges. (If straws are striped, use the stripes as a guide).
12. Replace the straw in the stack of sponges. You will likely require a new piece of plastic wrap before saturating the sponges.
13. Repeat steps 4-8 using the same amount of water as in step 4, and duplicate your assembly as closely as possible.
14. Record observations.

Data

Condition of Straw	Amount of Water to Start	Amount of Water Collected
Solid (no holes)		
Perforated (with holes)		

Observations

Conclusions

1. How did perforating (poking holes in) the straw change the amount of water you collected?

2. Using your observations, explain how perforating the well casing would be beneficial in a drilling scenario.

Extension

- Re-design this model to be more effective. Use different materials like sealable plastic bags, tape, etc.

Fracturing With Gelatin

Question

How does a liquid behave when injected into a solid under pressure?

Hypothesis

Materials

- 20 cc Syringe (oral dosing syringe works well)
- Breakfast syrup
- Butter knife
- Large disposable plate
- Flexible straws
- Plastic wrap
- Push pin or large sewing needle
- Paper towels
- Gelatin block (from your teacher)
- Warm water

Procedure

1. Your teacher will provide you with a block of gelatin on a plate.
2. Insert a straw into the side of the gelatin block, parallel to the plate, about 2/3 of the way into the gelatin.
3. Bore out the hole with the straw so a hole is left in the gelatin.
4. Poke about 10 holes in another straw. The holes should be near the end, away from the elbow, in two lines on opposite sides of the straw. The holes should be about 5 mm apart, and about 10 mm in from the end of the straw.
5. Cover the end of the perforated straw with a small piece of plastic wrap, to cover the holes while filling with fluid.
6. Attach the other end of the perforated straw, nearest the elbow, to the syringe with another piece of plastic wrap. Wind it around the straw and syringe several times to create a good seal.
7. Pull the plunger out of the syringe.
8. Fill the syringe with breakfast syrup, allowing it to run into the straw. Keep filling the syringe as the level goes down until the entire straw-syringe assembly is full of syrup.

9. Quickly replace the plunger into the syringe. This will keep the syrup from running freely out of the straw, but it still might drip a bit. Remove the plastic wrap covering.
10. Insert the perforated straw, filled with syrup and with syringe attached, into the bored hole in the gelatin block.
11. Using very firm pressure, quickly inject the syrup into the gelatin block and observe the fracturing pattern of the gelatin.
12. Pull the straw back out of the gelatin block.

Observations

Draw a picture of what you observe happening to the gelatin and the syrup.

⁂ Conclusions

1. What happened with the syrup and gelatin in this system? Why did they behave this way?

2. How does the syrup simulate a fracking fluid in the process of hydraulic fracturing?

Fracturing a Cake

Question

How does fracking fluid behave when entering a porous solid?

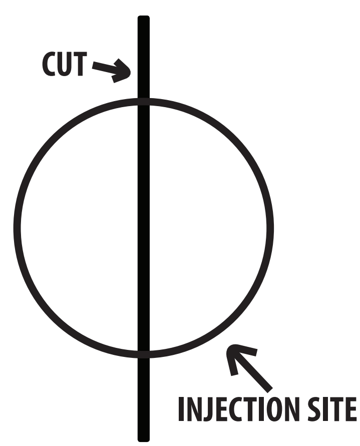
Hypothesis

Materials

- Frozen layer cake
- Turkey injector
- Chocolate Magic Shell® sundae topping
- Cup or beaker (optional)
- Plastic or metal knife

Procedure

1. Assemble the turkey injector syringe and needle.
2. Shake or swirl the Magic Shell® topping thoroughly in your container to prevent hardening.
3. Pour the Magic Shell® into the syringe of the injector. (Magic Shell® can also be drawn up into the syringe if using a beaker or cup. It is recommended that the injector is held over a cup or beaker to reduce mess, as the shell may slowly pour out of the bottom perforation of the injector needle.)
4. Insert the injector horizontally into the cake from the side. Aim to insert the injector into the middle or lower layer of the cake, not the top.
5. Quickly and firmly inject the fluid into the cake. (Steps 4-6 should occur quickly to avoid hardening of the Magic Shell®. If the fluid hardens, stir or shake and begin again.)
6. Repeat on other portions of the cake, if necessary.
7. Cut through your cake. Slice so that the knife travels vertically into your injection site creating a cross-section.
8. Observe how the fluid behaved in the porous cake. Draw a picture and describe your observations.



Observations

Conclusions

1. What happened to the Magic Shell® when it was injected into the cake?

2. What would happen to the Magic Shell® if the cake was more or less porous?

3. Did the Magic Shell® travel through the icing that separated the layers? Why do you think it behaved this way?

I'm Made From Oil and Natural Gas

Background

Oil and natural gas provide the basic materials from which plastic manufacturers make things we use every day.

Question

What is made from oil and natural gas that I use every day?

Materials

- Container of objects your teacher will provide

Procedure

1. Your teacher will place several objects from around your classroom that are made from oil and natural gas on a table. Look at the objects and see what they have in common. Your teacher will put the items back in the container.
2. When your teacher instructs you, write down as many objects from the container that you can remember.
3. Discuss with your teacher the kind of objects that are made from oil and natural gas.
4. Find a few other objects in your classroom that are made from oil and natural gas.

Observations

Which objects can you remember? Write them here.

List any objects you and your classmates found in the classroom that are made from oil and natural gas.

⁂ Conclusion

How many objects did you and your classmates list? Are there any things that you use every day, that are not in your classroom, that are made from oil and natural gas?

Research Questions

1. If oil and natural gas become more expensive, what happens to the price of things we use every day? What happens to objects made from oil and natural gas when we're done with them? Can we reuse them? Can they be recycled? Find out how your school, family, and community recycle plastic items.

A Nifty Natural Gas Story Pantomime

Students will demonstrate the flow of energy to heat homes using props. Depending on the audience, signs with the different forms of energy can be used by the students to identify the energy transformations. This activity with different props can also be used to demonstrate other energy flows, like coal to electricity, biodiesel, ethanol, etc.

Sun – Nuclear Energy		Nuclear fusion in the sun produces vast amounts of energy.
	Prop & Action	Yellow ball
Radiant Energy		The sun's radiant energy is transferred to Earth by electromagnetic waves.
	Prop & Action	Long pieces of yellow ribbon; students wave the ribbon in the air
Chemical Energy		Radiant energy is absorbed by tiny green plants in the ocean and changed to chemical energy by photosynthesis.
	Prop & Action	Artificial plants or paper "seaweed"; students move up from the floor and "float" around
Storing Chemical Energy		Tiny animals in the ocean ate the plants and stored their chemical energy.
	Prop & Action	Sock puppets; sock puppet animals "eat" the plants
Natural Gas Formation		The tiny plants and animals died. Over millions and millions of years, they were covered by many layers of dirt and rock. The high pressure changed them into natural gas.
	Prop & Action	Large pieces of brown and black paper and cardboard (several different types and colors); plants and sock puppets are dropped to the floor and the layers of "sediment" are stacked on top of them.
Natural Gas Exploration and Production		A well is drilled into the ground to locate natural gas. The gas is brought out of the ground through the well.
	Prop & Action	Long, hollow cardboard tube, or a rolled-up piece of paper; hold the tube vertically with hands over the head, and push the tube downward to the floor. Use one hand to wave fingers over the top of the tube in a wiggling motion to indicate the flowing of natural gas.
Separation, Dehydration, and Compression		The raw natural gas from the ground is separated from impurities and water, and compressed to high pressure.
	Prop & Action	Plastic mixing bowl or bottle; student uses hand to simulate separating the gas from the impurities, and another student pushes both hands together in a compressing motion to load the "gas" into the "pipeline"
Processing		At the processing facility, a chemical called mercaptan is added to the gas to make it smell like rotten eggs.
	Prop & Action	One long piece of garden hose or other tubing, and one eye dropper; one student holds the tubing from the separator to the processing facility, and one student holds the end of the tubing in one hand and the dropper in the other. The dropper is used to simulate adding mercaptan to the gas
Distribution		The processed gas is transported by pipeline to businesses and homes.
	Prop & Action	Another long piece of garden hose or other tubing; student holds it between the processing facility and the end use location
End Use – Thermal Energy		In our homes, natural gas is burned to heat water and keep us warm in cold weather.
	Prop & Action	Small lighter; student (or adult) lights the lighter and other students hold their hands up to the flame to indicate they are being warmed by the fire.

A Nifty Natural Gas Story

Hundreds of millions of years ago, long before the dinosaurs roamed, most of the Earth was covered with vast, deep oceans. Tiny plants and animals lived in these oceans.

The sun's radiant energy was changed into chemical energy by the plants, which helped them grow. The animals ate the plants, and both the plants and animals stored the sun's energy in their bodies as chemical energy.

When they died, they sank to the ocean floor. As more and more plants and animals died, they sank and made a thick layer deep under the water.

Over time, more layers of rock, sand, and other dead plants and animals built up. As the layers built up, they pressed down hard on the layers beneath.

As the layers of rock built up, the deepest layers got hot. They were under very high pressure with all that weight on top of them.

Eventually, those dead plants and animals under all those layers of rock changed. Now they weren't plants or animals. Now they were special molecules called hydrocarbons, with only hydrogen and carbon in them.

The hydrocarbons became trapped in tiny holes in the rocks. Then they waited.

And waited.

And waited some more - millions of years!

Many years ago, people began to notice bubbles coming out of the ground beneath ponds and lakes. They discovered that the bubbles were flammable – they could fuel a fire. The people used bamboo and other hollow plant stems to carry the bubbling gas to their villages.

Today, geologists search for the layers of rock that contain the hydrocarbons. They use a lot of special equipment and computers to find natural gas. Then they drill an exploratory well. Six times out of ten, they are successful!

The natural gas is pumped out of the ground at the well. It is separated from any liquids and water that might be mixed with it, and compressed into high pressure gas pipelines. The gas moves to the processing facility.

Natural gas has no odor, so at the final processing facility, a chemical called mercaptan is added. Mercaptan smells like rotten eggs! That is what you smell if natural gas is leaking.

After processing, electric power plants might use natural gas to generate electricity for homes, businesses, and schools. Most homes also use natural gas to heat water and stay warm in cold weather.

Natural gas produces less air pollution than other fossil fuels when it is burned. Because it is flammable, it is important to use it safely. If you ever smell natural gas, leave the area immediately and then call 911.

All of those tiny plants and animals millions of years ago are now providing us a clean energy source that is easy to use. Do you think they would be happy to know so many people rely on them?

Pretzel Power

Background

Oil and natural gas are widely used as transportation fuels. Most of our cars run on petroleum. Some vehicles are more efficient than others and allow us to go farther with less fuel while being kind to the environment.

Question

How might transportation choices affect our ability to get around?

Materials

- One 3" x 5" card or label
- Bag of 10 pretzels from your teacher

✔ Procedure

1. Think about the kind of car you would like to drive.
2. Use a computer and look at the fuel efficiency of your choice using www.fueleconomy.gov.
3. On your card, record the name of the car, the year it was made, how many miles per gallon it travels, and how many passengers can fit in the car.
4. Your teacher will give you a bag of pretzels. Each pretzel represents one gallon of gasoline and the bag represents one tank of gas.
5. **For Round One:** You will be "driving" from "Home" to work in "Near Town" and back home again while using only 5 gallons of gasoline (5 pretzels). You will be marking the distance driven by taking steps heel-to-toe. One step represents one mile driven.
   - Eat one pretzel. Take as many heel-to-toe steps as your car would be able to drive on one gallon of gasoline. Do not take any more steps than your car can drive.
   - Eat another pretzel and again take as many steps as your car can drive on one gallon of gasoline. Continue this until you have used five "gallons of gasoline" (eaten five pretzels).
6. **For Round Two:** In this round you will be traveling to "Far Town" in your car. Decide if you should carpool, and find passengers for your car, or join another person's carpool.
   - If you carpool, all members combine their pretzels. Only one person may eat a pretzel at a time.
   - When your teacher indicates the start of Round Two, begin stepping as a group as you drive to Far Town. Count the steps together for the car you chose to drive.

⁂ Conclusion

1. During Round One, were you able to make it to Near Town and back Home? Did you have fuel remaining?

2. During Round Two, were you able to make it to Far Town and back Home? How were you able to travel this greater distance?

3. Describe how this activity compares to driving real cars using real fuels.

4. Explain the benefits of carpooling. Describe the disadvantages, too.

Research Questions

1. Use the same website (fueleconomy.gov) that you used at the beginning of this activity to research your family's car(s). Discuss it with your family.
2. Look at some of the cars listed on the website. Which ones are the most fuel efficient? Are they cars you would choose to drive? What are the advantages and disadvantages to owning these cars?
3. What might cause a person to choose a different fuel for his or her vehicle? How can different fuels affect the range, performance, and mileage of a vehicle?

2006 Chevrolet Suburban 1500 2WD

CLASS	SUV
NUMBER OF PASSENGERS	7
FUEL	Gasoline/E85
COMBINED MPG	14 (gas)/11 (E85)
MAXIMUM RANGE	430/340

2007 Honda Accord

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	25
MAXIMUM RANGE	428

2006 Dodge Caravan

CLASS	Minivan
NUMBER OF PASSENGERS	7
FUEL	Gasoline
COMBINED MPG	20
MAXIMUM RANGE	400

2007 Hyundai Santa Fe 2WD

CLASS	SUV
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	21
MAXIMUM RANGE	416

2006 Ford Focus

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	25
MAXIMUM RANGE	350

2008 Ford Escape Hybrid 4WD

CLASS	SUV
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	28
MAXIMUM RANGE	420

2007 Toyota Camry

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	24
MAXIMUM RANGE	444

2008 BMW 335ci Manual Convertible

CLASS	Subcompact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	20
MAXIMUM RANGE	322

2008 Cadillac Escalade AWD

CLASS	SUV 4WD
NUMBER OF PASSENGERS	8
FUEL	Gasoline
COMBINED MPG	14
MAXIMUM RANGE	364

2009 Jeep Liberty 2WD

CLASS	SUV 2WD
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	18
MAXIMUM RANGE	351

2008 Volkswagen New Beetle Convertible

CLASS	Minicompact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	23
MAXIMUM RANGE	334

2009 Saturn Vue Hybrid

CLASS	SUV 2WD
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	28
MAXIMUM RANGE	504

2008 Volvo V50 AWD

CLASS	Small Station Wagon
NUMBER OF PASSENGERS	5
FUEL	Premium Gasoline
COMBINED MPG	21
MAXIMUM RANGE	332

2009 Aston Martin DBS Coupe - Manual

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	13
MAXIMUM RANGE	266

2009 Dodge Caliber

CLASS	Small Station Wagon
NUMBER OF PASSENGERS	5
FUEL	Premium Gasoline
COMBINED MPG	22
MAXIMUM RANGE	299

2009 Nissan Xterra 4WD

CLASS	SUV 4WD
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	17
MAXIMUM RANGE	359

2010 Acura RL

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	18
MAXIMUM RANGE	349

2010 Dodge Viper Coupe

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	16
MAXIMUM RANGE	256

2010 Bentley Continental GT

CLASS	Luxury Compact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	13
MAXIMUM RANGE	309

2010 Ford Taurus FWD

CLASS	Large Sedan
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	22
MAXIMUM RANGE	418

2010 Buick Lucerne FFV

CLASS	Large Sedan
NUMBER OF PASSENGERS	5
FUEL	Gasoline/E85
COMBINED MPG	20 (gas)/15 (E85)
MAXIMUM RANGE	370/278

2010 Hummer H3T4WD

CLASS	Pickup 4WD
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	16
MAXIMUM RANGE	432

2010 Chevrolet HHR FFV

CLASS	SUV 2WD
NUMBER OF PASSENGERS	5
FUEL	Gasoline/E85
COMBINED MPG	25 (gas)/17 (E85)
MAXIMUM RANGE	400/272

2010 Hyundai Elantra

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	29
MAXIMUM RANGE	406

2010 Mazda 6

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	24
MAXIMUM RANGE	444

2011 Chevrolet Malibu FFV

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline/E85
COMBINED MPG	26 (gas)/18 (E85)
MAXIMUM RANGE	416/288

2010 Toyota Prius

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	50
MAXIMUM RANGE	595

2011 Honda Fit

CLASS	Small Station Wagon
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	30
MAXIMUM RANGE	318

2011 Audi S5 Cabriolet

CLASS	Subcompact
NUMBER OF PASSENGERS	4
FUEL	Premium Gasoline
COMBINED MPG	20
MAXIMUM RANGE	338

2011 Kia Forte Eco

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	3
MAXIMUM RANGE	411

2011 Bugatti Veyron

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	10
MAXIMUM RANGE	264

2011 Lexus RX 450h

CLASS	SUV
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	30
MAXIMUM RANGE	516

2011 Mini Cooper Convertible

CLASS	Minicompact
NUMBER OF PASSENGERS	4
FUEL	Premium Gasoline
COMBINED MPG	30
MAXIMUM RANGE	396

2012 Azure Dynamic Transit Connect

CLASS	Van, Special Purpose
NUMBER OF PASSENGERS	2
FUEL	Electric
COMBINED MPG	62e
MAXIMUM RANGE	56

2011 Porsche 911 Carrera 4S Targa

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	20
MAXIMUM RANGE	354

2012 BMW Active Hybrid 7

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	20
MAXIMUM RANGE	434

2011 Subaru Outback AWD

CLASS	SUV 4WD
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	24
MAXIMUM RANGE	444

2012 Cadillac CTS Supercharger

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Premium Gasoline
COMBINED MPG	14
MAXIMUM RANGE	252

2011 Toyota Yaris

CLASS	Subcompact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	31
MAXIMUM RANGE	344

2012 Coda

CLASS	Subcompact
NUMBER OF PASSENGERS	4
FUEL	Electric
COMBINED MPG	73e
MAXIMUM RANGE	88

2012 Ferrari 458 Italia Spider

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	14
MAXIMUM RANGE	318

2012 Fiat 500 Abarth

CLASS	Minicompact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	31
MAXIMUM RANGE	326

2012 GMC Acadia AWD

CLASS	SUV 4WD
NUMBER OF PASSENGERS	8
FUEL	Gasoline
COMBINED MPG	19
MAXIMUM RANGE	418

2012 Jaguar XJ LWB

CLASS	Large Luxury Sedan
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	18
MAXIMUM RANGE	391

2012 Land Rover Range Rover Sport

CLASS	SUV 4WD
NUMBER OF PASSENGERS	5
FUEL	Premium Gasoline
COMBINED MPG	15
MAXIMUM RANGE	345

2012 Lincoln MKT FWD

CLASS	SUV 2WD
NUMBER OF PASSENGERS	7
FUEL	Gasoline
COMBINED MPG	20
MAXIMUM RANGE	372

2012 Maserati Quattroporte

CLASS	Large Luxury Sedan
NUMBER OF PASSENGERS	5
FUEL	Premium Gasoline
COMBINED MPG	15
MAXIMUM RANGE	357

2012 Mitsubishi i-MiEV

CLASS	Subcompact
NUMBER OF PASSENGERS	4
FUEL	Electric
COMBINED MPG	112e
MAXIMUM RANGE	52

2012 Rolls-Royce Phantom Coupe

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Premium Gasoline
COMBINED MPG	14
MAXIMUM RANGE	369

2013 BYD e6

CLASS	Small SUV
NUMBER OF PASSENGERS	5
FUEL	Electric
COMBINED MPG	63e
MAXIMUM RANGE	127

2012 Scion XD

CLASS	Subcompact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	29
MAXIMUM RANGE	322

2013 Chevrolet Volt

CLASS	Compact
NUMBER OF PASSENGERS	5
FUEL	Plug-in Hybrid
COMBINED MPG	98e/37 (gas)
MAXIMUM RANGE	38e/380

2013 Honda Civic CNG

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	CNG
COMBINED MPG	31e
MAXIMUM RANGE	193

2013 Dodge Charger FFV

CLASS	Large Sedan
NUMBER OF PASSENGERS	5
FUEL	Gasoline/E85
COMBINED MPG	23 (gas)/17 (E85)
MAXIMUM RANGE	439/325

2013 Nissan Leaf

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Electric
COMBINED MPG	115e
MAXIMUM RANGE	75

2013 Ford E350 Wagon

CLASS	Van, Passenger
NUMBER OF PASSENGERS	12
FUEL	Gasoline
COMBINED MPG	11
MAXIMUM RANGE	396

2013 GMC Sierra C15 XFE

CLASS	Standard Pickup
NUMBER OF PASSENGERS	3
FUEL	Gasoline/E85
COMBINED MPG	18 (gas)/13 (E85)
MAXIMUM RANGE	468/338

2013 smart fortwo Coupe Electric

CLASS	Minicompact
NUMBER OF PASSENGERS	2
FUEL	Electric
COMBINED MPG	107e
MAXIMUM RANGE	68

2013 Jeep Wrangler Unlimited

CLASS	Small SUV
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	18
MAXIMUM RANGE	405

2013 Toyota Rav 4

CLASS	Small SUV
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	26
MAXIMUM RANGE	413

2013 Mercedes-Benz S400 Hybrid

CLASS	Large Sedan
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	21
MAXIMUM RANGE	500

2014 Audi Q5

CLASS	Small SUV
NUMBER OF PASSENGERS	5
FUEL	Diesel
COMBINED MPG	27
MAXIMUM RANGE	535

2013 Ram 1500 4WD

CLASS	Standard Pickup
NUMBER OF PASSENGERS	3
FUEL	Gasoline/E85
COMBINED MPG	19 (gas)/13 (E85)
MAXIMUM RANGE	494/338

2014 Buick LaCrosse eAssist

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	29
MAXIMUM RANGE	458

2014 Chrysler 300 FFV

CLASS	Large Sedan
NUMBER OF PASSENGERS	5
FUEL	Gasoline/E85
COMBINED MPG	23 (gas)/17 (E85)
MAXIMUM RANGE	439/325

2014 Mini JCW Countryman

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	26
MAXIMUM RANGE	322

2014 Ford Edge

CLASS	Small SUV
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	22
MAXIMUM RANGE	403

2014 Ford C-max Energy Plug-in

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Plug-in Hybrid
COMBINED MPG	88e/38 (gas)
MAXIMUM RANGE	20e/550

2014 Honda Accord

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Plug-in Hybrid
COMBINED MPG	115e/46 (gas)
MAXIMUM RANGE	13e/570

2014 Pagani Huayra Coupe

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	13
MAXIMUM RANGE	250

2014 McLaren MP4-12C Spider

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	18
MAXIMUM RANGE	250

2014 Subaru Forester AWD

CLASS	Small SUV
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	27
MAXIMUM RANGE	429

2014 Kia Soul

CLASS	Small Station Wagon
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	26
MAXIMUM RANGE	369

2015 Chevrolet Impala bi-fuel

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Gasoline/CNG
COMBINED MPG	20 (gas)/19 (CNG)
MAXIMUM RANGE	368/119

2014 Volkswagon Passat

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Diesel
COMBINED MPG	34
MAXIMUM RANGE	629

2015 Chrysler Town & Country FFV

CLASS	Minivan
NUMBER OF PASSENGERS	7
FUEL	Gasoline/E85
COMBINED MPG	20 (gas)/14 (E85)
MAXIMUM RANGE	400/280

2014 Volvo XC60

CLASS	Small SUV
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	21
MAXIMUM RANGE	388

2015 Dodge Viper SRT

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	15
MAXIMUM RANGE	240

2015 Acura TLX

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Premium Gasoline
COMBINED MPG	28
MAXIMUM RANGE	482

2015 Fiat 500e

CLASS	Minicompact
NUMBER OF PASSENGERS	5
FUEL	Electric
COMBINED MPG	116e
MAXIMUM RANGE	87

2015 GMC Sierra K15 FFV

CLASS	Standard Pickup 4WD
NUMBER OF PASSENGERS	4
FUEL	Gasoline/E85
COMBINED MPG	17 (gas)/12 (E85)
MAXIMUM RANGE	442/312

2015 Lincoln MKS

CLASS	Large Sedan
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	22
MAXIMUM RANGE	418

2015 Hyundai Veloster

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	30
MAXIMUM RANGE	396

2015 Mazda MX-5

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	23
MAXIMUM RANGE	292

2015 Infiniti Q50 Hybrid

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Hybrid
COMBINED MPG	31
MAXIMUM RANGE	552

2015 Nissan Juke

CLASS	Small Station Wagon
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	30
MAXIMUM RANGE	396

2015 Jeep Grand Cherokee

CLASS	SUV 4WD
NUMBER OF PASSENGERS	5
FUEL	Gasoline/E85
COMBINED MPG	19 (gas)/15 (E85)
MAXIMUM RANGE	467/369

2015 Tesla Model S 90 kWh

CLASS	Large Sedan
NUMBER OF PASSENGERS	5
FUEL	Electric
COMBINED MPG	89e
MAXIMUM RANGE	265

2015 Toyota Prius Plug-in

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Plug-in Hybrid
COMBINED MPG	95e/50 (gas)
MAXIMUM RANGE	11e/450

2016 Chevrolet Corvette

CLASS	Sports Car
NUMBER OF PASSENGERS	2
FUEL	Premium Gasoline
COMBINED MPG	21
MAXIMUM RANGE	388

2015 Volkswagon Jetta

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Diesel
COMBINED MPG	36
MAXIMUM RANGE	522

2016 Ford Mustang Convertible

CLASS	Subcompact
NUMBER OF PASSENGERS	4
FUEL	Gasoline
COMBINED MPG	24
MAXIMUM RANGE	372

2016 Audi S4

CLASS	Compact
NUMBER OF PASSENGERS	4
FUEL	Premium Gasoline
COMBINED MPG	21
MAXIMUM RANGE	338

2016 Kia Optima Hybrid

CLASS	Midsize
NUMBER OF PASSENGERS	5
FUEL	Hybrid
COMBINED MPG	38
MAXIMUM RANGE	703

2016 BMW 328i XDrive Sports Wagon

CLASS	Small Station Wagon
NUMBER OF PASSENGERS	4
FUEL	Premium Gasoline
COMBINED MPG	26
MAXIMUM RANGE	411

2016 Porsche Cayenne Diesel

CLASS	SUV
NUMBER OF PASSENGERS	5
FUEL	Diesel
COMBINED MPG	23
MAXIMUM RANGE	607

2016 smart fortwo Coupe Electric

CLASS	Minicompact
NUMBER OF PASSENGERS	2
FUEL	Gasoline
COMBINED MPG	36
MAXIMUM RANGE	277

2016 Ford Escape Hybrid 4WD

CLASS	Small SUV
NUMBER OF PASSENGERS	5
FUEL	Gasoline
COMBINED MPG	26
MAXIMUM RANGE	403

2016 Toyota Sienna

CLASS	Minivan
NUMBER OF PASSENGERS	7
FUEL	Gasoline
COMBINED MPG	21
MAXIMUM RANGE	420

2016 Volvo XC90 PHEV

CLASS	SUV
NUMBER OF PASSENGERS	5
FUEL	Plug-in Hybrid
COMBINED MPG	53e/25 (gas)
MAXIMUM RANGE	14e/350

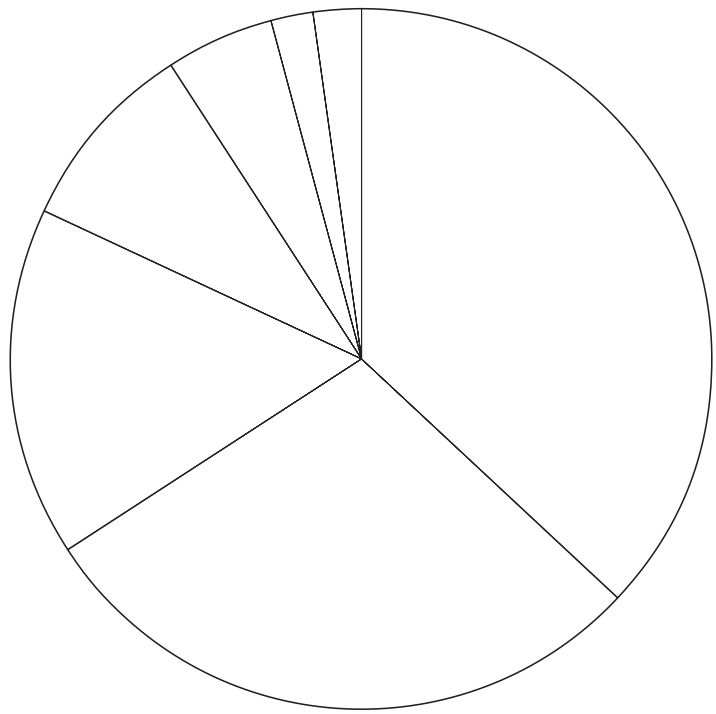
Energy Source Use Circle Graph

Directions

Using the data below, label the sections of the circle graph. The data below represents the amount of total energy each source of energy provided in 2015.

Petroleum	37%
Natural Gas	29%
Coal	16%
Uranium	9%
Biomass	5%
Hydropower	2%
Other (Solar, Wind, Geothermal)	2%

*Propane is included in petroleum and natural gas.



Color each section, and create a legend for the colors. Label each section with the correct percentage. Using the graph and what you know about energy sources, answer these questions.

1. Which energy source provides the most energy?

____

2. What percentage are renewable energy sources?

____

3. What percentage are nonrenewable energy sources?

____

4. What percentage of the energy sources are fossil fuels?

____

5. What percentage of the energy sources are found underground?

____

Oil and Natural Gas Math

Read each problem below. Plan how you will solve the problem, then solve it showing your work. Circle your answer.

1. A barrel of petroleum is 42 gallons. If a tanker barge can hold 27,500 barrels, how many gallons is it carrying?

2. The average personal car is driven 12,000 miles each year. If the car averages 25 miles per gallon, how many gallons of gasoline does it use each year?

3. After being refined, a barrel of petroleum makes about 20 gallons of gasoline.
   A. How many gallons of gasoline come from one tanker barge? (see problem #1)

   B. How many cars from problem #2 can be fueled for one year with the gasoline from one tanker barge?

4. If one large tanker truck can carry 8,000 gallons of petroleum, how many tanker trucks would it take to transport the same load as one barge (27,500 barrels)?

5. A tanker car on a train can hold an average of 30,000 gallons of petroleum products. How many tanker cars would be needed to replace one tanker barge?

OIL AND NATURAL GAS BINGO

A. Knows the main component of natural gas

B. Can name a state that is a top 5 producer of petroleum

C. Knows what percentage of oil used in the U.S. is imported

D. Knows how natural gas is measured

E. Knows two ways to increase a car's MPG

F. Knows what percentage of U.S. electricity is generated by natural gas

G. Knows the type of rock most petroleum is found in

H. Knows two products that can be made from natural gas

I. Knows what percentage of total energy is supplied by petroleum

J. Used petroleum to get to the workshop today

K. Knows two uses of natural gas in the home

L. Knows the two types of atoms found in oil and natural gas molecules

M. Has seen crude oil

N. Knows the method refineries use to separate crude oil into useful products

O. Knows how natural gas is transported

P. Knows what OPEC stands for

A NAME	**B** NAME	**C** NAME	**D** NAME
E NAME	**F** NAME	**G** NAME	**H** NAME
I NAME	**J** NAME	**K** NAME	**L** NAME
M NAME	**N** NAME	**O** NAME	**P** NAME

Glossary

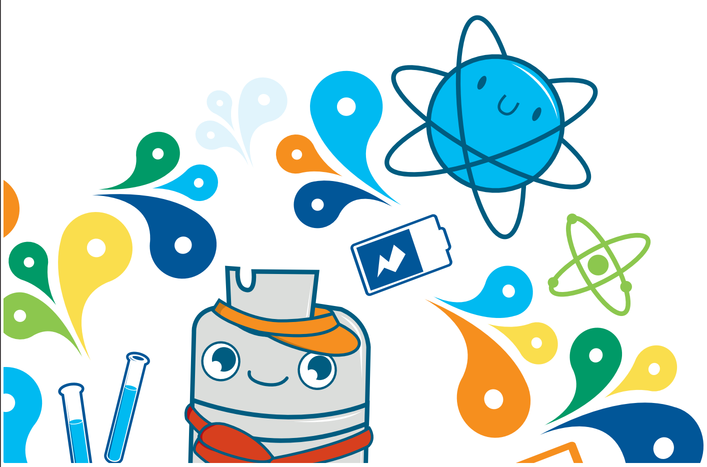
carnivore	animal that eats primarily other animals
chemical energy	energy stored in the chemical bonds of molecules in substances like petroleum, coal, wood, and food
commercial	part of society where business, education, and religious services occur
compound	pure substance made of groups of atoms chemically bonded together
compressed	pushed in from all directions and reduced in volume
crude oil	see oil; see petroleum
density	amount of volume a certain mass occupies; the mass of an object divided by its volume is its density
electricity	a form of energy; moving electrons
energy	ability to do work or undergo change
fault	crack in the Earth's crust; boundary between two plates in the Earth's crust
flammable	able to be burned
fossil fuel	nonrenewable sources of energy formed from living things that died many years ago
fractional distillation	process that separates compounds by their boiling points
geologists	scientists who study the Earth and its layers
geology	the study of the Earth
habitat	specific area or environment where people, animals, and plants live
herbivore	animal that eats only plants
horizontal	running parallel to the ground (parallel to the horizon)
hydraulic fracturing	a type of drilling that uses liquids to break up rocks and allows oil and gas to flow
igneous rock	rock made when lava cools
ignite	set on fire
industry	part of society that makes raw materials and finished products
lava	magma that has made it to the surface of the Earth
liquefaction	converting natural gas to a liquid
magma	molten rock found between the inner core and crust of the Earth
mercaptan	class of carbon-containing compounds that also has at least one sulfur atom, and has a very disagreeable odor

metamorphic rock	igneous or sedimentary rock that was subjected to intense heat and pressure and has changed; the grains of metamorphic rock are flattened, compared to sedimentary rock grains
methane	smallest of the hydrocarbons; one carbon atom bonded to four hydrogen atoms (CH_4)
microscopic	too small to be seen without a microscope
natural gas	a mixture of clear, colorless, odorless gases found in sedimentary rocks, made mainly of methane
nonrenewable	substance available in limited amounts; substance that cannot be made quickly
odorant	chemical added to a substance to give it a distinctive odor
oil	a mixture of hydrogen and carbon found in sedimentary rocks; another name for petroleum
omnivore	organism that eats both plants and animals
petroleum	a liquid found in sedimentary rocks, made mainly of hydrocarbons and turned into products like gasoline
photosynthesis	process when plants use light from the sun to make food
pipeline	long stretch of pipes connected together used to transport liquids and gases over great distances
pore	tiny hole or opening
porosity	the number of pores or openings in a rock
radiant energy	energy released by stars that travels in rays outward from the star
refinery	commercial complex that takes crude oil and separates it into its various compounds
regasification	converting LNG back into a gas
residence	part of society where people live
sediment	pieces of rock, soil, clay, and dirt
sedimentary rock	rock type formed by layers of sand and silt deposited at the bottom of a lake or ocean
sugar	an energy-rich substance made by plants
transportation	part of society that moves people and goods from one place to another
vertical	running perpendicular to the ground; running toward the center of the Earth

YOUTH ENERGY CONFERENCE AND AWARDS

The NEED Youth Energy Conference and Awards gives students more opportunities to learn about energy and to explore energy in STEM (science, technology, engineering, and math). The annual June conference has students from across the country working in groups on an Energy Challenge designed to stretch their minds and energy knowledge. A limited number of spaces are available for Full STEM Ahead, a special two-day pre-conference event, which allows students access to additional information, time to discuss energy with their peers, and access to industry professionals. The conference culminates with the Youth Awards Ceremony recognizing student work throughout the year and during the conference.

For More Info: www.youthenergyconference.org



YOUTH AWARDS PROGRAM FOR ENERGY ACHIEVEMENT

All NEED schools have outstanding classroom-based programs in which students learn about energy. Does your school have student leaders who extend these activities into their communities? To recognize outstanding achievement and reward student leadership, The NEED Project conducts the National Youth Awards Program for Energy Achievement.

Share Your Energy Outreach with The NEED Network!
This program combines academic competition with recognition to acknowledge everyone involved in NEED during the year—and to recognize those who achieve excellence in energy education in their schools and communities.

What's involved?

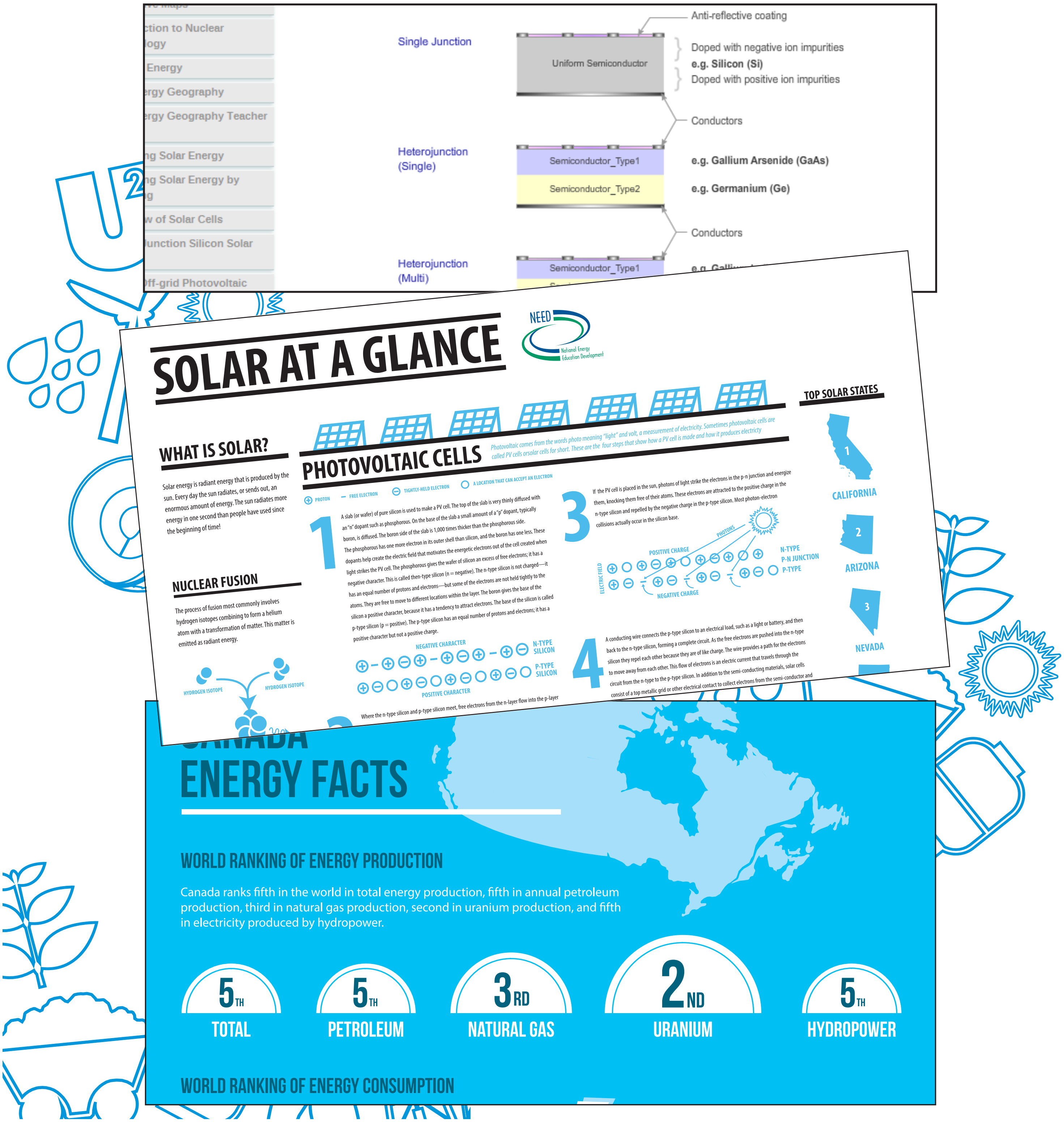
Students and teachers set goals and objectives and keep a record of their activities. Students create a digital project to submit for judging. In April, digital projects are uploaded to the online submission site.

Want more info? Check out **www.NEED.org/Youth-Awards** for more application and program information, previous winners, and photos of past events.

Awesome Extras!

Our Awesome Extras page contains PowerPoints, animations, and other great resources to compliment what you are teaching!

This page is available at www.NEED.org/educators.



NEED's Online Resources

NEED'S SMUGMUG GALLERY

http://need-media.smugmug.com/

On NEED's SmugMug page, you'll find pictures of NEED students learning and teaching about energy. Would you like to submit images or videos to NEED's gallery? E-mail info@NEED.org for more information.
Also use SmugMug to find these visual resources:

Videos
Need a refresher on how to use Science of Energy with your students? Watch the Science of Energy videos. Also check out our Energy Chants videos! Find videos produced by NEED students teaching their peers and community members about energy.

Online Graphics Library
Would you like to use NEED's graphics in your own classroom presentations, or allow students to use them in their presentations? Download graphics for easy use in your classroom.

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THE BLOG

We feature new curriculum, teacher news, upcoming programs, and exciting resources regularly. To read the latest from the NEED network, visit www.NEED.org/blog_home.asp.

EVALUATIONS AND ASSESSMENT

Building an assessment? Searching for standards? Check out our Evaluations page for a question bank, NEED's Energy Polls, sample rubrics, links to standards alignment, and more at www.NEED.org/evaluation.

E-PUBLICATIONS

The NEED Project offers e-publication versions of various guides for in-classroom use. Guides that are currently available as an e-publication can be found at www.issuu.com/theneedproject.

SOCIAL MEDIA

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NEED ENERGY BOOKLIST

Looking for cross-curricular connections, or extra background reading for your students? NEED's booklist provides an extensive list of fiction and nonfiction titles for all grade levels to support energy units in the science, social studies, or language arts setting. Check it out at www.NEED.org/booklist.asp.

U.S. ENERGY GEOGRAPHY

Maps are a great way for students to visualize the energy picture in the United States. This set of maps will support your energy discussion and multi-disciplinary energy activities. Go to www.need.org/energyinsocietymaterials to see energy production, consumption, and reserves all over the country!

Wonders of Oil and Natural Gas Evaluation Form

State: ____________ **Grade Level:** ____________ **Number of Students:** ___________

1. **Did you conduct the entire unit?**	❑ Yes	❑ No
2. **Were the instructions clear and easy to follow?**	❑ Yes	❑ No
3. **Did the activities meet your academic objectives?**	❑ Yes	❑ No
4. **Were the activities age appropriate?**	❑ Yes	❑ No
5. **Were the allotted times sufficient to conduct the activities?**	❑ Yes	❑ No
6. **Were the activities easy to use?**	❑ Yes	❑ No
7. **Was the preparation required acceptable for the activities?**	❑ Yes	❑ No
8. **Were the students interested and motivated?**	❑ Yes	❑ No
9. **Was the energy knowledge content age appropriate?**	❑ Yes	❑ No
10. **Would you teach this unit again?**	❑ Yes	❑ No

Please explain any 'no' statement below.

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

____

____

____

____

Other Comments:

____

____

____

____

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News Articles and Peer-reviewed Publications

Can Fracking Be Environmentally Acceptable?

Jay N. Meegoda, Ph.D., P.E., F.ASCE[1]; Samuel Rudy[2]; Zhenting Zou[3]; and Michael Agbakpe, Ph.D.[4]

Abstract: The hydraulic fracturing or fracking and extraction of shale gas is vital to the continued success of the human race to provide a relatively clean energy source. However, there are several environmental issues that must be solved in order to make fracking environmentally acceptable. Once these issues are resolved, it could lead to a brighter future by allowing shale gas to act as a bridge to clean energy, while providing energy independence for the United States. To achieve these goals, there is a need to find suitable solutions to the following problems: methane gas leaks while fracking and during production, trigger of earthquakes due to fracking, and the disposal of the wastewater (largely comprised of fracking fluid) after the completion of fracking. To investigate the aforementioned environmental impacts, comprehensive research was performed using data for the Marcella formation. Although it is clear that additional research must be performed to fully deal with all the issues, the following strategies have been found to solve or mitigate the problems. To prevent the impact of methane gas leaks, well workers must be properly trained and supervised. As another precaution to prevent the methane from contaminating groundwater, groundwater wells must be a minimum of 1 km away from the vertical section of fracking wells. To lessen the intensity and frequency of earthquakes caused by fracking, a regulation should be set in place that prevents disposal of wastewater by groundwater injection wells. In addition, the site should be checked for possible active and inactive faults before the approval of fracking. Finally, fracking companies must be required to withdraw most fluids from wells and to treat them according to state regulations and reuse or surface disposal as treated water. If all of these suggestions are implemented, fracking can be made much more environmentally viable and safe. **DOI: 10.1061/(ASCE)HZ.2153-5515.0000330.** © *2016 American Society of Civil Engineers.*

Author keywords: Methane; Fracking; Environmental impact; Groundwater contamination; Earthquakes; Wastewater.

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Introduction

Fracking is the process of drilling into the earth before a high-pressure water mixture is directed at the rock to fracture and subsequently release the shale gas trapped inside. The components of the water mixture are primary: water, sand, and chemicals are injected into the rock at high pressure, which allows the gas to flow out to the head of the well. In the United States, it has significantly boosted domestic oil production and driven down energy prices. A published review (Petroleum Resources Branch 2011), fracking is estimated to have offered gas security to the United States and Canada for the next 100 years, and has presented an opportunity to generate electricity at half the CO_2 emissions from coal (Nature 2009).

The U.S. Energy Information Administration (EIA) estimated that as of January 1, 2012 there were about 6.42×10^{13} cubic meter [2,266 trillion cubic feet (tcf)] of technically recoverable resources of dry natural gas including 2.08×10^{13} cubic meter (736 tcf) of shale gas (EIA 2015) in the United States. According to the EIA database, a remarkable boom of shale gas occurred during the past decade. Fig. 1 shows the annual natural gas production and future projection in the United States and Fig. 2 shows the percentage of all sources of natural gas in total production. Before 2000, the shale gas accounted for only about 1% in total natural gas production. Thereafter, rapid and considerable growth in production numbers was observed. In 2013, about 2.43×10^{11} cubic meter (8.6 tcf) of dry natural gas was produced from shale gas, amounting to almost 35% of total natural gas production in the United States. The seed for the shale gas boom was planted in the late 1970s when the U.S. government decided to fund government research and development programs and provided tax credits for developing unconventional natural gas in response to the severe natural gas shortage at the time (Wang and Krupnick 2013). Some key technologies such as horizontal drilling and three-dimensional exploration resulted from that program. During the 1970s, hydraulic fracturing started to extract shale gas. In 1997, Mitchell Energy took the fracturing technique used in east Texas by Union Pacific Resources and applied it to the Barnett Shale formation of north Texas (Robbins 2013), and found that this technology can be used to exploit gas in a cost-effective manner.

Hydraulic fracturing is presently the primary extraction technique for oil and gas production in low or tight permeability, unconventional reservoirs (Gallegos and Varela 2014). As of the year 2013, at least 2 million wells have been hydraulically fractured, and in addition up to 95% of new wells drilled currently are hydraulically fractured (U.S. DOE 2013). During hydraulic fracturing, water containing chemical additives and propping agents are injected into a low-permeability petroleum reservoir under high pressure, fracturing the formation (Tanya et al. 2015). A single shale gas well requires approximately 9,000 to 29,000 m^3 (2.0 to 6.4 million gal.) of water (U.S. DOE 2009). Over 82,000 wells were fracked since 2005, using approximately 9.5×10^8 m^3 (250 billion gal.) of water in addition to adding 7.6×10^6 m^3 (2 billion gal.) of chemicals to fracking wells (Ridlington and Rumpler 2013) and subsequently generating large quantity of wastewater.

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Note. This manuscript was submitted on February 3, 2016; approved on April 25, 2016; published online on June 20, 2016. Discussion period open until November 20, 2016; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Hazardous, Toxic, and Radioactive Waste***, © ASCE, ISSN 2153-5493.

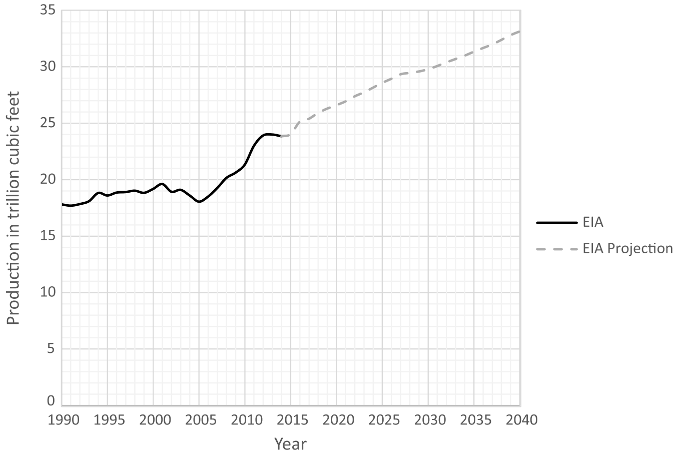

Fig. 1. Total U.S. natural gas production and projection production

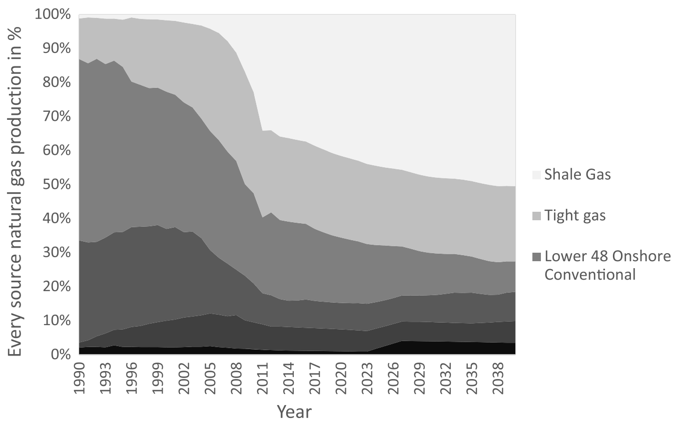

Fig. 2. Natural gas production by source

Hydraulic fracturing, more commonly referred to as fracking, is older than most people presume it to be. The inspiration for the earliest version of fracking came when Civil War veteran Colonel Edward Roberts witnessed, "Exploding artillery rounds plunging into the narrow millrace canal" during a battle. Roberts later patented an "exploding torpedo" device to carry the process that Roberts referred to as fluid tamping, which become the earliest form of hydraulic fracturing (AOGHS 2014). The next big leap towards modern fracking did not occur until the 1930s, when nitroglycerin was replaced with a nonexplosive fluid substitute termed acid, increasing the productivity of wells by making them less likely to close. The first research into modern fracking was performed in the late 1940s and during the remainder of the century, both the popularity and the technology (such as drilling techniques and extraction methods) of fracking expanded (Cahoy et al. 2012). George Mitchell, who combined fracking with horizontal drilling (Zuckerman 2013), developed the final technological leap of fracking in the 1990s. As shown in Fig. 3, the horizontal drilling can be performed for several hundred to thousand meters inside the shale layer and extract shale gas over larger area. This vastly increased the efficiency while reducing the deleterious environmental impacts.

Fracking includes several steps as shown in Fig. 4. Before the start of vertical drilling, a well casing made of cement must be installed deeper than the groundwater to protect the aquifer. Drilling mud is used to lubricate the drill and protect the borehole. After the desired depth is reached, horizontal drilling into the gas

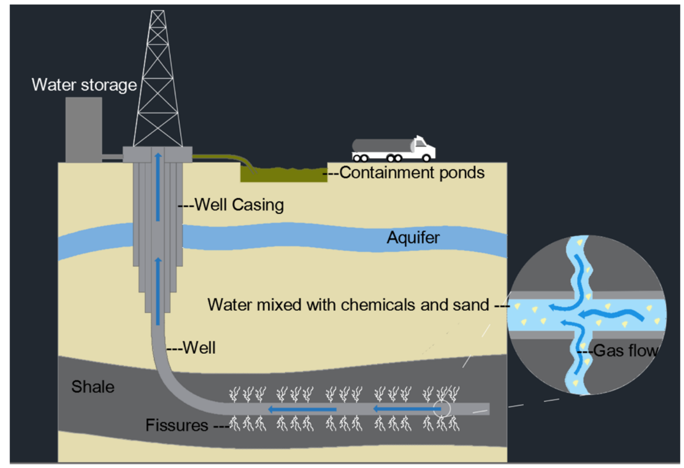

Fig. 3. Shale gas extraction

shale layer is accomplished by gradually tilting the drill and drilling horizontally. The horizontal drilling will continue for several thousand feet inside the shale layer. After drilling, a production casing surrounded with cement will be installed in the borehole. Then plugs are added to prepare the separate fracturing stages. A perforating gun is sent to the horizontal borehole to blast small holes into the shale. Then, the high-pressure fracking fluid is pumped into the borehole to create fissures in the shale. These fissures provide free paths for the gas to flows to the surface. One well can be fractured at multiple locations, and when the fracking is completed, the fracking fluid is stored in a wastewater pond once it is pumped out to the surface. As stated before, fracking fluid contains water, sand, and chemicals. The function of the sand in the fracking fluid is to prevent the closing of created fissures. Approximately 10 to 20 chemicals are added to the fracking fluid, with each having a specific purpose such as polyacrylamide to reduce the friction between fluid and pipe and ethylene glycol to prevent scale deposit in the pipe (U.S. EPA 2015).

Fracking allows countries such as the United States great economic benefits. The current low gas prices can be in part attributed to fracking. For example, Brookings Institute has reported an average decrease of $13 billion per year in consumer gas bills due to fracking from 2007 to 2013 (Hausman and Kellogg 2015). Not only is fracking saving money for American citizens, but it is also providing a wealth of employment opportunities in America. In addition to the economic benefits, fracking provides political advantages to the United States. One of the main foreign policy issues of America is its dependence on foreign oil for energy. The widespread popularity of fracking could vastly reduce this dependency, giving other countries less control over the United States.

The recent push to develop unconventional sources of oil and gas both in the United States and abroad via hydraulic fracturing (fracking) has generated a great deal of controversy (Boudet et al. 2014). Concerns about possible risks associated with public health and water quality arising from the migration of chemicals in the fracking fluid and methane gas into local groundwater aquifers. Methane gas can also escape into the atmosphere, adding to the greenhouse effect. The quantity of water required for the hydraulic fracturing process is also of concern especially in the arid and semiarid regions (Davis 2012). These concerns are heightened largely by the unwillingness of fracking companies to divulge the content of the fracking fluid to the public and their unwillingness to be subjected to regulatory policies, thereby creating the perception of possible deception and cover-up. This have mainly created a fertile ground for speculation among the public. This atmosphere has also

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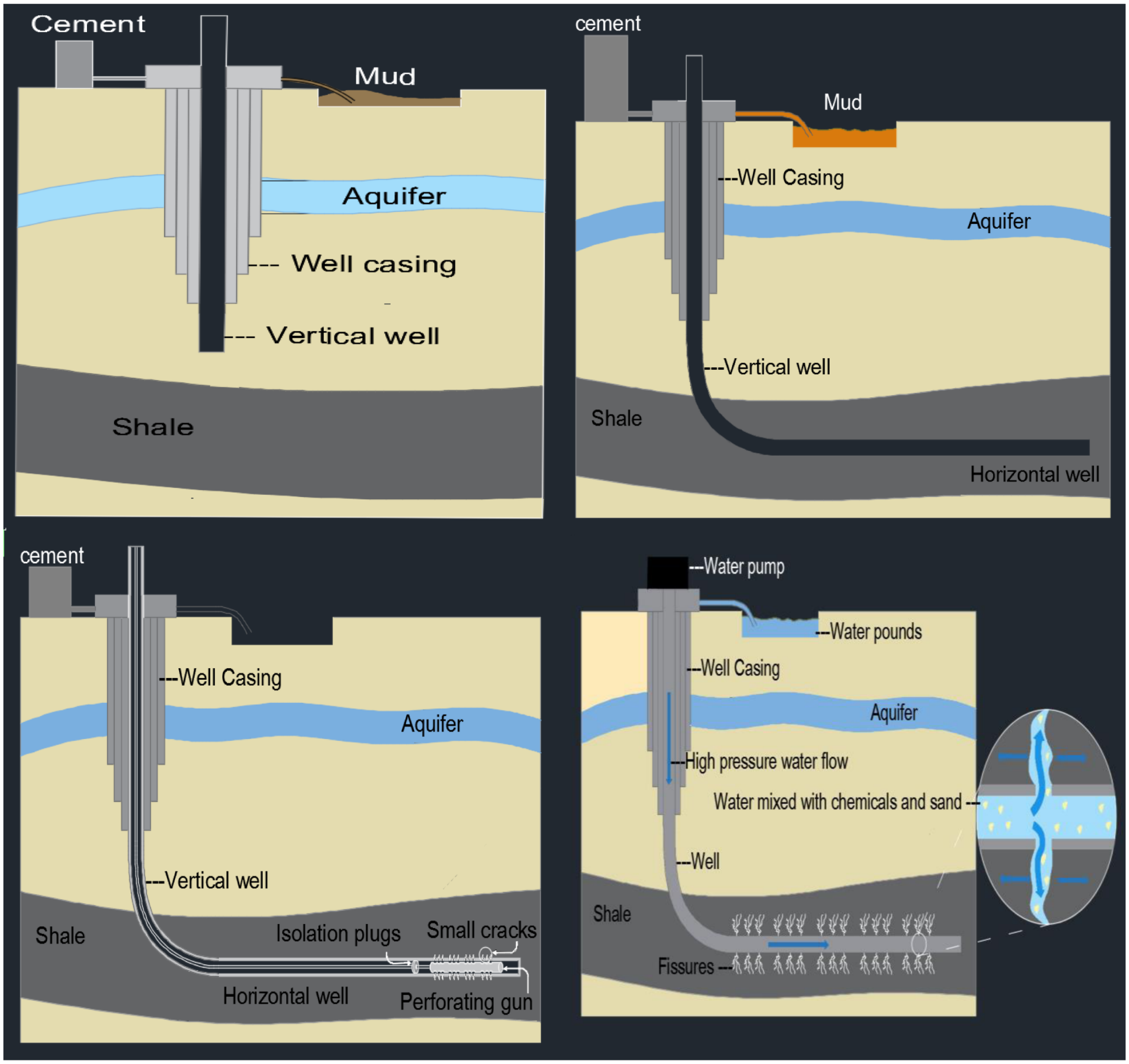

Fig. 4. How the fracking is performed

made it difficult for researchers and scientists to undertake factual studies evaluating potential environmental impacts of the process, which will help to decipher and different between the legitimate and perceived concerns of the public, thereby putting the technology on the path to eventual public acceptance. Effectively engaging stakeholders and setting appropriate policies requires insights into current public perceptions of this issue (Boudet et al. 2014). The current main issues of public concerns are described in the following sections.

Groundwater Contamination

The most likely cause for methane and fracking fluid contamination of groundwater is "poorly built wells- inadequate steel casing and poor cement construction" (North Carolina Health News 2014). Proper sealing of annular spaces with cement creates a hydraulic barrier to both vertical and horizontal fluid migration (FracFocus .org 2015a, b, c). In some situations, a buildup of localized pressure occurs because of inadequately seal pipes, which results in the release of gas and drilling fluids into the natural environment (Lustgarten 2009). Therefore, human error is most likely liable for contamination of groundwater around fracking wells. Avoidance of this requires strict regulatory monitory in construction and verification methods using geophysical logs such as cement bond logs (CBL) and variable density logs (VDL) to evaluate the sealing quality of the cement in the annulus (FracFocus.org 2015a, b, c). Another source of contamination of groundwater typical of methane is from other naturally occurring shallow pockets that are drilled through to assess the deep shale formations.

Air Pollution

Gas wells are connected to many valves and joints, and those may release pressure by venting gas. Recently, the amount of methane in the atmosphere has been increasing due to leaks from shale gas wells and loose pipefittings (Zeller 2011). Methane venting and leakage can be decreased by upgrading old pipelines and storage systems, and by applying better technology for capturing gas in the 2-week flow back period after fracking (Howarth et al. 2011a, b). Though shale gas contributes to greenhouse effects through leakage

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during gas extraction and carbon dioxide release during burning, it is less damaging than coal. The carbon footprint of shale gas estimated to be about 53% lower than coal (Laurenzi and Jersey 2013). In addition, burning of coal also emits metals such as mercury into the atmosphere that eventually settle back into our soils and waters (Brantley and Meyendorff 2013).

Large Volume Water Use in Water-Deficient Regions

Shale gas production on the average require approximately 15,000 m^3 (4 million gal.) of water per well. These varies from well to well in the range of 9,000 to 29,000 m^3 (2 to 6.4 million gal.) (U.S. DOE 2009). As reduction in water use is been advocated by promotion of fluid recycling whenever possible, the quantity of water demand for fracking has become a big issue for officials in water-scarce states concerned about balancing energy-related demands with those related to municipal consumption and irrigated agriculture (Davis 2012). The location of the fracking operation is also very important (Davis 2012). Conflicts resulting from competing demands for energy and water are of increasing global concern, especially in expanding urban areas (Fry et al. 2012). This conflicts of opposing demand of water will become more pronounced, especially in areas of scarce water resources, as shale gas extraction technologies gets rooted throughout the world.

Effect on Drinking Water Resources

According to the U.S. Environmental Protection Agency (EPA), the impact of hydraulic fracturing activities on drinking water resources depends on a couple of factors such as proximity to drinking water resources. Residents and drinking water resources in areas that experience hydraulic fracturing activities are most likely to be affected by any potential impacts. However, hydraulic fracturing can also affect drinking water resources outside the immediate vicinity of a hydraulically fractured well, as trucks carrying wastewater could spill or a release inadequately treated wastewater that could have downstream effects. Some other activities associated with hydraulic fracturing activities also have the potential to impact drinking water resources. These include water withdrawals in times of, or in areas with, low water availability, spills of hydraulic fracturing fluids and produced water, fracturing directly into underground drinking water resources, belowground migration of liquids and gases, and inadequate treatment and discharge of wastewater. They, however, did not find any evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources.

Blowouts due to Gas Explosion

Methane gas can escape into the environment out of any gas well, creating the real, though remote, possibility of dangerous explosions. However, unlike with oil exploration, for shale gas exploration this is a concern only during initial installation.

Due to the blowouts due to gas explosings and recent occurrence of earthquakes, hydraulic fracturing has recently experienced great opposition due to environmental issues commonly associated with it. Hence, all issues can be lumped into three major concerns: (1) the occurrence of methane contamination of groundwater and surface water herein referred to as "leaking methane gas," (2) the occurrence of earthquakes, and (3) the improper treatment methods and disposal of fracking fluid. This manuscript provides a detailed discussion of these three environmental issues to find an acceptable common ground to proceed with fracking for economic prosperity and energy security.

Leaking Methane Gas

As stated before, fracking is a process by which shale gas is extracted from thousands of feet below the earth. Methane gas is a major component of the shale gas and methane has been detected in groundwater reserves near extraction wells of shale gas. Since the primary purpose of fracking is to extract the methane gas, fracking has been accused of contaminating the groundwater reserves with methane gas.

Methane (CH_4) is considered the second damaging greenhouse gas, and has a global warming potential of 25 over a 100-year period and 12 years of life in the atmosphere. In other words, methane can trap 25 times more heat than carbon dioxide in 100 years and can exist in the atmosphere for over a decade. Atmospheric CH_4 has increased by about 1,000 parts per billion since the beginning of the industrial era of the late 1700s, representing the fastest changes in this gas over at least the last 80,000 years (U.S. EPA 2010d, a). Methane emission occurs not only due to the human activities, but also due to natural causes such as wetlands and agricultural activities. However, over 60% of total methane emissions are due to human activities such as leakage form natural gas systems and from waste/landfills (U.S. EPA 2010a). In the atmosphere, methane will react with airborne particles called aerosols. Aerosols can affect climate directly by the scatter of solar radiation and indirectly by clouds (IPCC 2001). Emissions of methane have substantial impacts on aerosols by altering the abundance of oxidants, especially hydroxyl, which convert SO_2 into sulfate (Shindell et al. 2009). Global burdens of hydroxyl and sulfate change by −26 and −11% for methane (Shindell et al. 2009). When methane uses up hydroxyl, a lower sulfate aerosols concentration will be present in the atmosphere and less incoming light will be scattered, causing a warmer climate (IPCC 2001).

Fugitive emissions during the production and distribution of shale gas exploration are an inevitable and serious environmental issue. Emissions from natural gas production accounted for approximately 66% of CH_4 emissions and about 25% of nonenergy CO_2 emissions from the natural gas industry in 2006 (U.S. EPA 2010d, a). Emission during well completion; leakage from the equipment; and losses during distribution, processing, and transport are three main processes causing methane emission.

During the production process, methane emissions can occur due to two reasons. The first is emission from the well. During the construction, methane emission occurs when the plugs are drilled out and when the fracking fluid is recovered back to the ground surface. The U.S. EPA (2007) estimated drill-out emissions at 142×10^3 to 425×10^3 m^3 per well. After the fracking is completed, a significant amount of fluid returns to the surface as flow back within the first few days to weeks and is accompanied by large quantities of methane (Bol et al. 1991). With the development of the cracks, a large amount of gas is released and is dissolved in the fluid, exceeding the methane solubility in the fluid. Hence, when the fluid flows back it will contain a large amount of methane. With careful process designs, this methane can be recovered.

The second cause for methane emission is from the gaps between the casing, cement, and formation. There are already several protective measures to prevent methane leakage from the fracking wells and subsequent operation. The primary defense against methane gas leaking is the pipe that transports the methane gas from the shale layer, on the average of 2,133 m (7,000 ft) underground, to the surface where the gas is collected. Fracking companies have included several precautions to prevent methane gas leaks (Fig. 5). The specifics vary slightly based on the fracking company, but in general, the pipe that transports the methane has up to seven protective layers, with extra layers of cement when the

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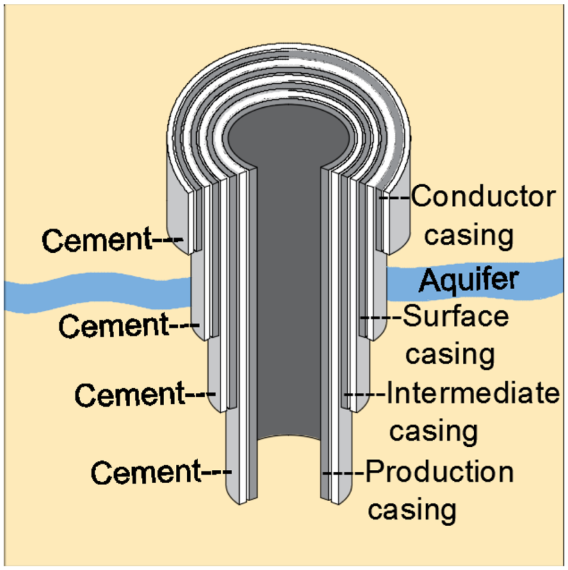

Fig. 5. Schematic of a section of vertical well

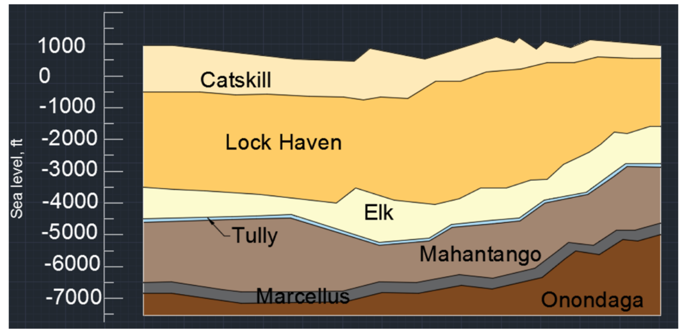

Fig. 6. Cross section of Marcella formation

pipe approaches the surface level. Typically, the seven layers include four casing layers and three cement layers between the casings. The objectives of these layers are to protect the groundwater, protect the well bore, and let the gas flows to the surface. Actually, the casing and cement are also set to isolate the water and subsurface formation. The number and size of the layer depend on each well's subsurface characteristics, such as depth of groundwater table, groundwater bearing, and rock formation. Normally, the four casing layers include conductor casing, surface casing, intermediate casing, and production casing. Conductor casing has two primary purposes: to hold back any unconsolidated surface sediments and to isolate shallow groundwater from the content in the well (Encana 2015). It has varied size and length from 24 to 46 m (80 to 150 ft). After the conductor casing is installed, the drilling will begin. To control the well and provide blowout protection, second layer, called the surface casing, is installed and cemented. The size of this layer depends on the depth of the deepest groundwater table, usually up to 610 m (2,000 ft). The third layer is called intermediate casing and it is used to protect the well bore and to avoid the instability caused by abnormally pressured subsurface formation. This layer casing a cement top must isolate any hydrocarbon zones (Petrowiki 2015). The final layer is the production casing, which carries the fracking fluid and the path for the gas to flow to the surface after fracking. Casing and cement play an important role in groundwater protection.

Due to aforementioned measures, it is highly unlikely that the methane would leak from the well, in the absence of a poorly built well due to human error. However, when the integrity of the well bore is compromised, gas migration or stray gas can become an issue (Harrison 1983). The emission may occur when the cement and the casing are not properly set and cause a gap between the casing and the cement. Such emissions can also occur between the formation and the cement. The well is drilled into a deep formation with high-pressure gas, and this high-pressure gas can have deleterious effects on the integrity of the outer cement annulus, such as the creation of microchannels (Bol et al. 1991). Due to the high working pressures, the design of the cement is important. If the hydrostatic pressure of the cement column is not higher than the gas-bearing formation pressure, the gas can fracture the cement before it sets and a loss of cement slurry can occur (Vidic et al. 2013). Fractures of the cement and gaps between the cement and the formation can occur due to these reasons. Hence, the integrity of the vertical well should be carefully checked before horizontal drilling.

In addition to the reasons mentioned earlier, emissions from pneumatic pumps and dehydrators comprise major parts of the leakage (GAO 2010). A typical well has 55 to 150 connections to equipment such as heaters, meters, dehydrators, compressors, and the vapor-recovery apparatus (Howarth et al. 2011a, b). During the production, the well is connected through many different valves and those may release pressure by venting gas. Aging equipment and improper sealing of the pipe or equipment will allow methane to be released from the system. The GAO (2010) concluded that 0.3–1.9% of the lifetime production of a well is lost due to routine venting and equipment leaks. Other emissions occur during processing, transport, and distribution. The default EPA facility-level fugitive emission factor for gas processing indicates a loss of 0.19% during production (Shires et al. 2009). Due to the difficulty in measuring the losses during the transport and distribution, there is no proper direct quantification from these two losses. However, there are methane monitors in the market that could trigger alarms and locate such leaks.

A high level of protection does not safeguard against methane gas that migrates to the groundwater from the shale layer (without ever passing through the pipe). This situation is thought to occur in horizontally drilled wells. Horizontal drilling is a more efficient version of fracking than the original vertical drilling. In horizontal drilling, once the well has reached a desired depth, the trajectory of the drill slowly changes continually until the drill creates a horizontal well. This allows a larger area to be fracked with less disturbance to the surface within a shorter period. However, it is assumed that horizontal drilling has a fatal drawback; it causes methane at the shale layer to migrate through the thousands of feet of rock, to the groundwater. This is thought to occur when the well is fractured (explosions are detonated in order to create cracks in the shale layer and the retrieval of the shale gas) and the shale gas is redisturbed.

Fig. 6 shows a cross-section of Marcella shale; Table 1 shows its hydraulic properties. The following computation is performed to estimate the time (t) of arrival of shale gas to the surface. Vertical hydraulic conductivity, K_v, is given as

$$K_v = \frac{\sum_{i=1}^{n} H_i}{\sum_{i=1}^{n} \frac{H_i}{K_{v_i}}} \tag{1}$$

where H_i = average thickness of each rock type in the Marcella formation and K_{v_i} = hydraulic conductivity of each rock type.

Therefore, from Eq. (1), the vertical hydraulic conductivity (K_v) of the Marcella formation is estimated as

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$$K_v = \frac{305 \text{ m} + 792 \text{ m} + 152 \text{ m} + 30 \text{ m} + 610 \text{ m} \,(1{,}000 \text{ ft} + 2{,}600 \text{ ft} + 500 \text{ ft} + 100 \text{ ft} + 2{,}000 \text{ ft})}{\frac{305 \text{ m} (1{,}000 \text{ ft})}{1.52\times10^{-6} \text{ m/day} (5\times10^{-6} \text{ ft/day})} + \frac{792 \text{ m} (2{,}600 \text{ ft})}{1.52\times10^{-6} \text{ m/day} (5\times10^{-6} \text{ ft/day})} + \frac{152 \text{ m} (500 \text{ ft})}{1.52\times10^{-3} \text{ m/day} (5\times10^{-3} \text{ ft/day})} + \frac{30 \text{ m} (100 \text{ ft})}{1.52\times10^{-3} \text{ m/day} (5\times10^{-3} \text{ ft/day})} + \frac{610 \text{ m} (2{,}000 \text{ ft})}{3.05\times10^{-9} \text{ m/day} (10^{-8} \text{ ft/day})}}$$
$$= 9.45 \times 10^{-9} \text{ m/day} \,(3.1 \times 10^{-8} \text{ ft/day})$$

The hydraulic gradient i is defined as

$$i = \frac{P}{L \times \gamma w} \tag{2}$$

where P = reservoir pressure [$P = 27.6$ MPa (4,000 psi = 576,000 psf)]; L = average depth of the shale formation to the ground water table [$L = 1,890$ m (6,200 ft)]; and γw = unit weight of water [$\gamma w = 9.8 \text{ kN/m}^3 (62.4 \text{ pcf})$].

Substituting the values into Eq. (2) gives the hydraulic gradient as

$$i = \frac{27,579 \text{ kPa}}{1,890 \text{ m} \times 9.8 \text{ N/m}^3}\left(\frac{576,000 \text{ psf}}{6,200 \text{ ft} \times 62.4 \text{ pcf}}\right) = 1.32$$

The Darcy velocity (Vd) is expressed as

$$Vd = K_v \times i \tag{3}$$

Hence, from Eq. (3), the Darcy velocity can be written $Vd = 9.45 \times 10^{-9}$ m/day (3.1×10^{-8} ft/day) $\times 1.32 = 1.25 \times 10^{-8}$ m/day (4.092×10^{-8} ft/day).

Average linear seepage velocity, Vs, is given as

$$Vs = \frac{Vd}{n} \tag{4}$$

Assuming an average porosity (n) of 8.0%, then from Eq. (4)

$$Vs = \frac{1.25 \times 10^{-8} \text{ m/day}}{0.08}\left(\frac{4.092 \times 10^{-8} \text{ ft/day}}{0.08}\right)$$
$$= 1.56 \times 10^{-7} \text{ m/day } (5.115 \times 10^{-7} \text{ ft/day})$$

Hence, the time (t) of arrival of the shale gas to the groundwater is estimated below as 33 million years

$$t = \frac{L}{Vs} = 1,890 \text{ m } (6{,}200 \text{ ft})/[1.56 \times 10^{-7} \text{ m/day } (5.115 \times 10^{-7} \text{ ft/day})]/(365 \text{ day/year}) = 33 \text{ million years}$$

Please note that methane diffusion could also occur due to the methane concentration gradient, but the time for methane to reach the surface is much longer than 33 million years. Fick's second law was used to estimate the time it takes to increase the atmospheric concentration of methane by 10% due methane gas migration by diffusion. The resulting time was computed as 470 million years. The diffusion coefficient was assumed to be $0.022 \text{ m}^2/\text{day}$ ($0.24 \text{ ft}^2/\text{day}$) (Chen et al. 1977). Hence, it is virtually impossible for methane to contaminate the groundwater due to horizontal drilling and can be considered as a perceived environmental concern.

While it has been proven that most of the accusations against fracking causing methane contamination are false, there is still undeniably a presence of methane in the groundwater around some fracking locations. The most likely culprit for this methane contamination is "poorly built wells- inadequate steel casing and poor cement construction (North Carolina Health News 2014)." In other words, human error is most likely responsible for any contamination of groundwater around fracking wells. This is because there is high pressure in the pipe during fracking. Specifically, when the fracking fluid is pumped into the well and when the methane gas is pumped out of the well. Even a small irregularity in the casing due to poor installation or cementation could produce a leak, such as a full water balloon pricked with a tiny hole (Ewen et al. 2012). From that leak, it is feasible that the methane gas could slip past the cement and contaminate the groundwater.

As with horizontal drilling, this situation is not the case. Studies have shown that there is a negligible amount of contamination if the groundwater is more than 1 km away from fracking wells (Mason et al. 2015). Hence, it is proposed that any residential or commercial activities should be at least 1 km away from the vertical well. While this would be inconvenient for fracking companies as there is groundwater above many of the places that contain shale gas, it is definitely possible to work around. This is especially true when horizontal fracking is considered (which has already shown not to be the cause of methane contamination). Horizontal fracking could be used to circumvent the 1-km restriction by drilling down vertically more than 1 km away from the groundwater and then drilling horizontally underneath the groundwater. As it is now, horizontal wells extend several miles, so the 1-km constraint would not be overly detrimental to the productiveness of fracking.

There is another possible explanation for methane contamination. Groundwater naturally contains methane in low quantities. However, it is possible that some groundwater has a larger concentration of methane. The preceding time of arrival calculation showed that it would take approximately 33 million years for methane to seep from the shale layer up to the groundwater reserves. Yet, most of the shale formations that are fracked are far older than that of the Marcellus shale (the second largest fracking field in the world), which is 385 million years old. With such a long time, it is possible that the shale migrated into the groundwater long before fracking was even conceived and that it was only noticed once fracking became popular and controversial. This explanation is corroborated by reports (Lustgarten 2009) of people being able to set their water aflame (due to the high methane concentration) long before fracking began in their area.

Between human error and natural methane migration into groundwater, the presence of methane in groundwater around fracking wells can be explained. It is also evident that fracking does not inherently cause contamination of groundwater, provided that

Table 1. Hydraulic Properties of Rock in Marcella Formation

Formation[a]	Rock type[b]	Thickness[a] [m (ft)]	Hydraulic conductivity[c] [m/day (ft/day)]
Catskill	Sandstone	305 (1,000)	1.52×10^{-6} (5×10^{-6})
Lock haven	Siltstone, shale, sandstone	792 (2,600)	1.52×10^{-6} (5×10^{-6})
Elk	Dolomite, shale	152 (500)	1.52×10^{-3} (5×10^{-3})
Tully	Limestone	30 (100)	1.52×10^{-3} (5×10^{-3})
Mahantango	Shale	610 (2,000)	$3.05 \times 10^{-9} (10^{-8})$

[a]Data from Molofsky et al. (2011).
[b]Data from Harper (1999).
[c]Data from Domenico and Schwartz (1990).

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the vertical well is at least 1 km away from any groundwater well. Therefore, with sufficient training and supervision to avoid most human error, along with the proper regulation preventing fracking companies from drilling vertically within 1.6 km (1 mi) of groundwater, the process of fracking can be made safe, and prevent methane from contaminating groundwater reserves.

Earthquakes

Another environmental concern due to fracking is the occurrence of earthquakes near fracking sites. Although the direct link between earthquakes has not been definitively proven, there are viable theories for how fracking could directly cause earthquakes and the level of correlation between fracking and earthquakes makes a cause and effect relationship between the two undeniable. The earthquakes tend to occur mainly during two steps of the fracking: (1) during the injection of the fracking fluid into the well and (2) after the fracking is completed, when the fracking companies inject waste fluid into deep underground formations. The vast majority of the earthquakes attributable to fracking are not powerful enough to be detected by humans without the aid of a sensor; however, a larger earthquake could occur infrequently with the potential to cause damage.

Currently, there are only a few preventative measures employed by fracking companies to prevent earthquakes (partially due to the ambiguous cause and nature of the earthquakes). One such protective measure utilized by Cabot Oil and Gas Corporation (along with other fracking companies) is to perform a detailed sonar analysis of the ground before fracking (Fetzer 2012). Unfortunately, this technique has proven insufficient in preventing earthquakes.

The most likely cause of the earthquakes is either fracking fluid or waste fluid seeping into undetected faults deep underground when they the fluids are injected into their respective wells. The fluids are injected with high pressure underground and this great pressure may cause them to move through the fractures that are created during fracking, causing leakage from the fractures in the shale layer to fault lines. The fluid could then provide lubrication and cause the fault to slip, creating earthquakes around the area.

A precaution that should be taken (in addition to screening the ground before beginning to frack) is to ensure that disposal wells are not overloaded, because overloading a well could increase the pressure and make earthquakes more frequent. It would not be feasible to lessen the pressure exerted by the fracking fluid because high pressure is needed in order for the fluid to create the fractures, keep them open, and extract the shale gas. Another proposed solution is to not frack within a certain range of a population due to the perception that earthquakes only occur in areas close to the well. This, however, has recently been disproved. A Cornell University research team measured earthquakes that were most likely attributed to fracking approximately 50 km (31 mi) away from the fracking wells (Keranen et al. 2014). The cause of these earthquakes has not yet been conclusively determined but it is suspected to be due to fracking. Katie Keranen, professor of geophysics at Cornell University, stated, "Existing criteria for an induced earthquake do not allow earthquakes associated with the well activity to occur this far away from the wellbore," implying that the current explanation for earthquakes is not due to fracking, or a given explanation is incomplete.

In a study on the impact of fracking on earthquakes, an investigation of the Marcella formation in the state of Pennsylvania was conducted. There are 301 fracking wells in Pennsylvania (FracFocus 2015a, b, c). Based on U.S. Geological Survey (USGS 2015) data, there were only six earthquakes of magnitude 4 or higher that occurred within the last 30 years. Earthquakes of magnitude 4 or less are considered a minor earthquake of minimal disruption. Upon further analysis of those six earthquakes, it was found that all occurred prior to fracking starting in Pennsylvania. Furthermore, the epicenter of those earthquakes was much deeper than the Marcella formation, indicating minimal or no contribution due to fracking in Pennsylvania, one of the major shale gas producers.

Despite the research performed, earthquakes remain one of the most mysterious issues associated with fracking. However, it is important to note that the issue of earthquakes is not as pressing as other environmental concerns surrounding fracking due to the infrequent occurrence of earthquakes and the far less likely chance that an earthquake occurs that could cause any damage. With the current research, the best solution would be to prohibit underground injection of waste fluid or at least prevent overfilling of disposal wells. In addition, it is important to check as thoroughly as possible for any fault or abnormality in the ground before drilling begins. If these preventative measures are followed, the likelihood of earthquakes, especially severe ones, should decrease.

Fracking Fluid

Handling of flow back and produced waters is another issue that arises from fracking operations. Currently, this wastewater can be recycled for subsequent fracking, reinjected underground, or treated and released into rivers. Other environmental issues are the impacts on land use, noise, and air quality. The exploration process in general generates a lot of activities and associated traffic, noise, and air pollution (Davis 2012). Despite the fact that the industry is adapting where possible to more benign fracking chemicals, information on the exposure to natural and added chemicals and the fate and ecotoxicity of the generated wastewater is not available (Batley and Kookana 2012).

High concentrations of natural contaminants such as metals, radionuclides, total petroleum hydrocarbons (TPHs), and phenols have also been observed in return wastewaters and formation waters (Cheung et al. 2009; Wood and Patterson 2011). Even though these chemicals are naturally occurring, there are risks of possible modification and release processes associated with the introduction of oxygenated waters, as ythe oxidation of reduced iron may lead to iron oxyhydroxide precipitation and a lowering of water pH (Batley and Kookana 2012). Elevated iron and manganese concentrations have been observed in flow-back waters (Wood and Patterson 2011). Acids in the fracking fluids will cause metal dissolution, aided by chelating agents. Surfactants and solvents may assist in the dissolution of organic compounds (Batley and Kookana 2012).

Therefore, a third major environmental issue is the disposal of waste products (mostly fracking fluid) after a well is fully formed for gas production. Different chemicals perform different functions in a hydraulic fracturing. Although there are dozens to hundreds of chemicals that could be used as additives, there are a limited number that are routinely used in fracking. Table 2 shows a list of the most frequently used chemicals.

Fracking fluid is pumped down into the well at high pressure and used to create, expand, and keep open the fissures created in the shale layer in order to allow the shale gas to be withdrawn from the well. Once the factures are initiated, the fracking fluid is retrieved. The proper disposal of fracking fluid remains an important environmental issue.

There are three processes that fracking wastewater can undergo. The most environmentally friendly is the first option, reusing the

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Table 2. Typical Composition of Fracking Fluid

Product function[a]	Chemical purpose[a]	Typical example[a]	Technology to remove
Acids	Helps dissolve minerals and initiate cracks in the rock	Hydrochloric Acid	pH control
Biocide	Eliminates bacteria in the water that produces corrosive by-products	Glutaraldehyde	Biodegradation
Breaker	Allows a delayed break down of the gel	Ammonium persulfate	Neutralization
Clay stabilizer	Prevents clays from swelling or shifting	Tetramethyl ammonium chloride	Oxidation
Corrosion inhibitor	Prevents the corrosion of the pipe	Acetaldehyde	Biodegradation
Cross-linker	Maintains fluid viscosity as temperature increases	Potassium metaborate	pH control
Friction reducer	Carrier fluid for polyacrylamide friction reducer	Petroleum distillate	Coagulation
Gelling agent	Product stabilizer and/or winterizing agent	Ethylene glycol	Biodegradation/Microfiltration
Iron control	Prevents precipitation of metal oxides	Thioglycolic acid	Biological activated carbon
Nonemulsifier	Prevent the formation of emulsions in the fracture fluid	Lauryl sulfate	Activated carbon
pH adjusting agent	Adjusts the pH of fluid to maintains the effectiveness of other components, such as cross-linkers	Sodium hydroxide	pH control
Scale inhibitor	Prevents scale deposits in the pipe	Copolymer of acrylamide and sodium acrylate	Microorganisms
Surfactant	Product stabilizer	2-Butoxyethanol	Activated carbon
Granular	Keep the factures open	Sand	Filtration

[a]Data from FracFocus.org (2015c).

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fracking fluid and treating the waste in a private treatment plant. As seen in Table 2, there are existing technologies to effectively treat or neutralize each component of fracking fluid. Waste still needs to be properly disposed even with this option. "The process cleans most of the water, but at least some smaller amount of fluid, or solid 'cake,' still needs to be disposed" (NPR 2014). This injection back into the ground is simiar to the second option: putting wastewater into a disposal well. This option involves injecting waste into a Class II disposal well (the type of well for fracking waste) and leaving it thousands of meters underground, commonly surrounded by sandstone or limestone. This option can have detrimental effects on the environment, and fracking fluid must be disposed of properly.

The treatment and renewal of fracking liquid waste are more important because some of these compounds are hazardous substances and known carcinogens, which can enter and pollute drinking water supplies from the well, well pad, or in the wastewater disposal process. Some of the listed additives are listed in Table 2 (FracFocus 2015a, b, c). Their adverse effects and removal strategies are discussed in the following.

Acetaldehyde, which is use as corrosion inhibitor, is considered a probable human carcinogen (Group B2) and has been shown to cause nasal tumors in rats and laryngeal tumors in hamsters (U.S. EPA 1997). Additionally, acetaldehyde cannot be effectively treated by traditional water-treatment processes, but was reported to be effectively removed by microbial degradation using biological activated carbon (BAC) filters (Chun-Lei et al. 2013).

Ethylene glycol is an organic solvent, and is a major constituent of antifreeze and coolant. It functions as a product stabilizer and/or winterizing agent in a fracking fluid mixture. Chronic exposure effects include kidney toxicity and liver damage. Several oral or inhalation exposure studies on rodents also showed that ethylene glycol is toxic to fetuses (U.S. EPA 1999). The EPA has not listed ethylene glycol as a controlled or priority substance, however. Ethylene glycol is reported to undergo aerobic and anaerobic biodegradation in water (Dwyer and Tiedje 1983); thus, ethylene glycol can be removed from the waste fracking fluid by biodegradation.

Another compound of interest is 2-Butoxyethanol, which functions as a product stabilizer in fracking. The EPA currently does not classify 2-Butoxyethanol for human carcinogenicity, but rather cautions against effects of acute and chronic exposures such as severe liver and kidney damage, testicular damage, reduced fertility, maternal toxicity, early embryonic death, birth defects, delayed development, and hematological disorders from inhalation and oral exposure (U.S. EPA 1984). Removal of 2-Butoxyethanol can be achieved with techniques like activated carbon filtration and ozone reaction.

Glutaraldehyde is a biocide with wide industrial applications. In fracking operations, it is used to eliminate bacteria in the water that produce corrosive by-products. Glutaraldehyde is acutely toxic to both aquatic and terrestrial organisms. Results from environmental partitioning indicated that glutaraldehyde is hydrophilic and tends to remain in the aquatic partition and is nonbioaccumulative (IPCS INCHEM 2005). Aqueous solutions of glutaraldehyde are stable at room temperature under acidic to neutral conditions, and stable in sunlight, but unstable at elevated temperatures and under alkaline conditions. Glutaraldehyde is biodegradable under both aerobic and anaerobic conditions (Leung 2001).

Ammonium persulfate is an inorganic salt that is highly soluble in water. It is a strong oxidizing agent, which is used in fracking liquid as a polymerization inhibitor to aid delayed break down of the gel. Ammonium persulfate is harmful to aquatic organisms (ILO-ICSC 2001). In human beings, it is reported to cause asthmatic effects (De Vooght et al. 2010). The substance can be absorbed into the body by inhalation in its aerosol form and by ingestion (ILO-ICSC 2001). Ammonium persulfate can be removed by neutralizing it with a base.

Tetramethyl ammonium chloride is used in fracking fluid as a clay stabilizer to prevent clays from swelling or shifting. Tetramethyl ammonium chloride is a nonvolatile quaternary ammonium salt, which exists in the cation form in the environment and generally adsorbs strongly to soils containing organic carbon and clay. It is reported to be toxic to microorganisms an also has a low bioaccumulative potential (TOXNET-HSDB 2012). It can be absorbed into the body by inhalation and by ingestion (CDC 2003). Above 300°C, tetramethyl ammonium chloride decomposes to produces ammonia, carbon monoxide, hydrogen chloride, and nitrogen oxides. It can also react with oxidants (ILO-ICSC 2003) and thus can be treated by oxidation.

Regulations need to be implemented that require companies to extract as much fracking fluid from the well bore as they reasonably can and dispose of it in an environmentally acceptable manner. The ideal solution would be to treat as much of the fluid as possible, but this is more expensive. One final consideration to consider when disposing of fracking fluid is to create a regulation that prevents overloading of disposal wells as this can cause other problems, primarily earthquakes and leaks.

The proper disposal of fracking fluid could lead to both environmental and economic benefits. If a technique for cheaply treating the wastewater is created, then only a minimal amount of fracking fluid will need to be disposed of and the rest can be reused in other fracking wells, leaving a smaller environmental footprint and allowing fracking companies to not have to acquire new fracking fluid. Additionally, with proper regulation and enforcement, most of the issues associated with disposal wells should be mitigated.

To make fracking safe, both for the environment and any citizens in the area, the issue of proper disposal of waste products must be solved. All of the remaining fracking fluid should be treated or disposed of in a manner in accordance with regulations that should be put in place to prevent issues with disposal. This should diminish the issues related to the correct disposal of wastewater.

Several studies have revealed the use of toxic fracking fluids such as diesel and benzene (Davis 2012). In the Energy Policy Act of 2005 the Halliburton loophole was added to the EPA's Resource Conservation and Recovery Act (RCRA), which regulates hazardous and solid waste, exempting from oversight the waste from oil and gas exploration, development, and production.

Cost and Benefit Analysis

A cost and benefits analysis of hydraulic fracking and production of shale gas is required to complete the evaluation. This is essential as studies addressing total lifecycle costs are rare and previous reports have come to different conclusions on the cost and environmental benefits of shale gas compared to other alternatives. Stamford and Azapagic (2014) demonstrated that shale gas has a wide range of lifecycle environmental impacts (favorable and unfavorable) depending on the potential variation of different parameters. Laurenzi and Jersey (2013) reported that the carbon footprint of Marcellus gas 53% lower than coal, and the freshwater consumption is about 50% less than coal. Weber and Clavin (2012) also reported that the most likely upstream carbon footprints are largely similar for both shale and conventional gas production, with overlapping 95% uncertainty ranges of 11.0–21.0 g CO_2e/MJ_{LHV} and 12.4–19.5 g CO_2e/MJ_{LHV} for shale and conventional gas, respectively. However, a complete cost benefit analysis of fracking considering environmental costs and benefits of issues discussed in this manuscript requires an in-depth analysis and is thus beyond the scope of the present work. A detailed study of the topic has been initiated for a future manuscript.

Regulations

The biggest issue with fracking is the lack of or minimal regulation. The federal government is unable to regulate the industry because of the Halliburton loophole in the Energy Policy Act of 2005; this clause excludes "underground injections of fluids or propping agents, other than diesel fuels, in hydraulic fracturing activities." Hence, regulatory oversight falls to the state, but states have competing monetary interests. The result of these conflicts of interest is to reduce the motivation or incentive to regulate the industry. Regulatory bodies are urgently needed to control the fracking fluids used. Furthermore, regulatory procedures should be put in place to ensure safety, prevent contamination, and make the involved parties responsible for violations (Ince et al. 2013). In the Energy Policy Act of 2005, the "Halliburton loophole" exempts fracking from the Safe Drinking Water Act because it was believed that fracking posed no risk to drinking water (Manuel 2010). The Clean Water Act and Clean Air Act encounter similar difficulties in enforcement. Therefore, the EPA has little to no actual authority over this booming industry. Other regulatory agencies that have a role in the fracking include the Underground Injection Control Program (UICP), which regulates the pumping of fluids into wells, and the National Pollutant Discharge Elimination System (NPDES), which regulates runoff from waste pits and surface spills (EPA). Both of these groups set standards for acceptable practices regarding aspects of the fracking process. However, UICP has very little control over the well injections under the 2005 Energy Policy Act; hence, UIP can only regulate the disposal of the fracking fluids in underground waste wells (Ince et al. 2013).

The current lack of regulations and oversight for the chemicals and wastewater of fracking is the main source of controversy and leads to a lack of confidence on the part of some stakeholders, hindering the wider public acceptance of the process. Regulation reform and proper oversight is urgently needed that should prioritize abatement of potential risks and to boost public confidence in the fracking process. The reform regulation should endeavor to embrace the concerns of all the stakeholders in an effort to provide social and economic benefits for the society.

Summary and Conclusions

Fracking, the process of drilling deep down and injecting high-pressure water mixture to fracture rock to release trapped shale gas, promises the potential of energy independence for the United States. It has presented an opportunity to generate electricity at half the CO_2 emissions from coal. There are three major environmental issues identified with fracking, namely, leaking methane gas while fracking and during production, triggering of earthquakes due to fracking, and the disposal of the wastewater. A comprehensive literature search and a detailed analysis were performed to address the question of whether fracking be environmentally acceptable. It can be concluded that if the following actions were taken, then fracking could indeed be made environmentally acceptable.

Earthquakes remain one of the most mysterious issues that has been associated with fracking, but there is no definitively proven direct link between earthquakes and hydraulic fracking. However, for the Marcella shale formation, earthquakes are not as pressing as other environmental concerns surrounding fracking due to the infrequent occurrence of earthquakes and the far less probability that such an earthquake occurs that could cause any damage. The vast majority of the earthquakes attributable to fracking are not powerful enough to be detected by humans without the aid of a sensor; however, a larger earthquake can occur infrequently with the potential to cause damage. With the current level of knowledge, the best precaution would be to prohibit underground injection of waste fluid. In addition, a complete geological investigation should be performed to locate any active or dormant faults or abnormality in the ground before drilling. Once it is confirmed that no such geological formations are found, the vertical wells should be located at least a mile away from any residential or commercial activities.

Based on shale gas seepage and diffusion calculations herein, it is virtually impossible for methane to contaminate the groundwater due to horizontal drilling. However, there is a possibility of shale gas release from a vertical well and it is proposed that any residential or commercial activities should be at least 1 km away from the vertical well. In addition, the vertical wells should be constructed with precautions to prevent methane gas leaks and a proper quality

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assurance and quality control procedure should be established during construction. Furthermore, the workers should be trained and properly supervised during construction. Methane monitors that could trigger alarms and locate leaks can be used in order to prevent losses during the transport and distribution.

To make fracking safe, the issue of proper disposal of waste products must be solved. Most fracking fluid should be extracted from the well bore and treated for reuse. The waste fracking fluid should be treated or disposed of in a manner in accordance with regulations that should be put in place. The proper disposal of waste fracking fluid could lead to both environmental and economic benefits. This should diminish the issues surrounding correct disposal of wastewater. Finally, regulation and openness are major issues limiting stakeholder acceptance of the process. Therefore, regulation reformation is vital to ensure that all shareholder concerns are addressed in an effort to provide social and economic benefits for society as a whole.

An in-depth cost-benefit analysis of fracking, considering environmental costs and benefits of issues discussed in this manuscript, is required. Then, new regulations can be put in place for locating new wells, construction of new wells, and recovery and proper disposal of fracking fluids. If the aforementioned suggestions are implemented, fracking can be made environmentally safe.

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The Texas Well That Started a Revolution

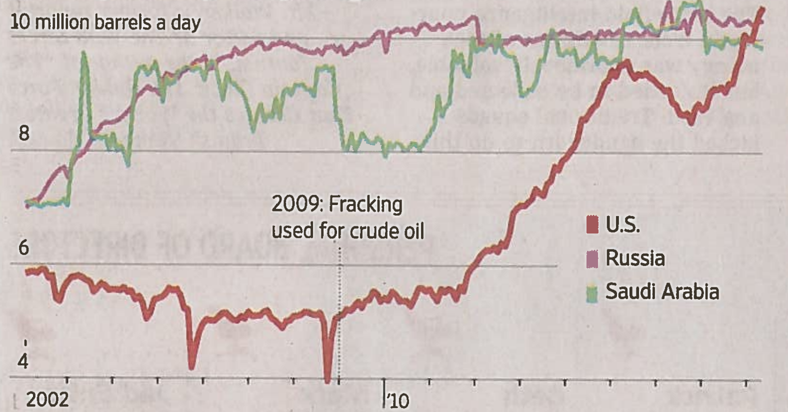
Two decades ago, an engineer got permission to try a new way to get gas out of the ground. Energy markets and global politics would never be the same.

BY RUSSELL GOLD

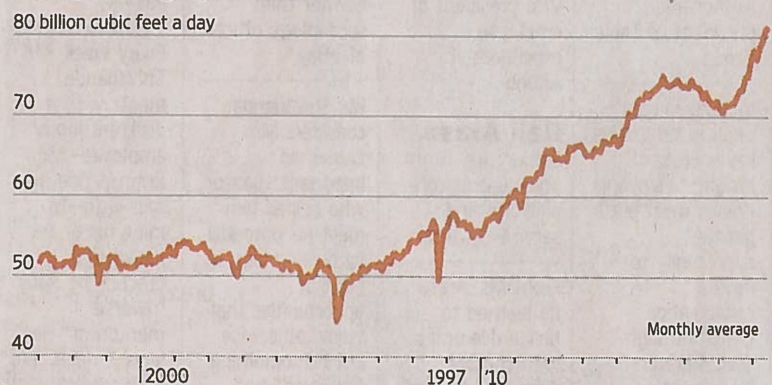
Seek And Ye Shale Find

The arrival of fracking helped turn the U.S. into an energy powerhouse. It's a major exporter of natural gas and became the world's largest producer of crude oil this year.

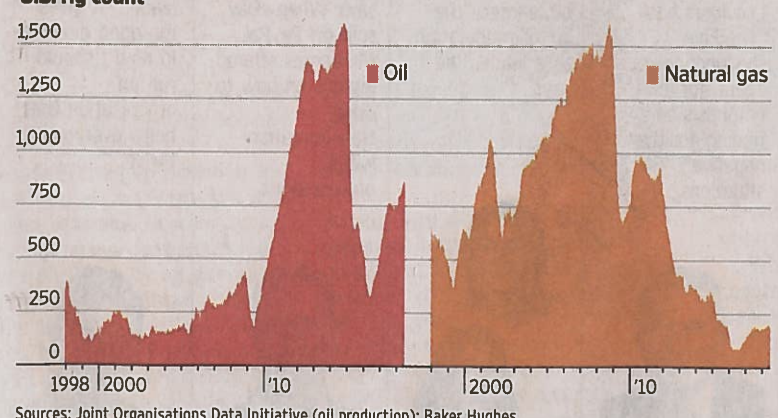
Crude-oil production, monthly average



U.S. dry natural gas production



U.S. rig count



Sources: Joint Organisations Data Initiative (oil production); Baker Hughes (rig count); U.S. Energy Information Administration (natural gas production) THE WALL STREET JOURNAL.

Twenty years ago, a well was drilled in Dish, Texas, that changed the world.

Nothing at the time suggested the unassuming well in the rural town north of Fort Worth would hobble OPEC, the powerful oil cartel that had governed prices of the world's most important commodity for more than a generation. Or that it would help turn the U.S. into a global energy exporter, or shuffle the geopolitical deck.

But it did all of that—and more. The well used hydraulic fracturing to crack the incredibly tight shale rocks below. It fired the first shot in the fracking revolution—a blast soon felt in Riyadh, Tehran and Moscow.

"I had no idea it would cause so much change. I was just trying to keep my job," said Nick Steinsberger on a recent visit to the well pad. He was the engineer who obtained permission to try a new approach to completing the well that had been drilled a mile and a half deep into a thick gray wedge of rock known as the Barnett Shale.

Mr. Steinsberger, now 54, called the experiment "my slick-water frack." It was the first commercially successful use of sand, water and chemicals, pumped into the shale under high pressure, to break open the rock and unleash the natural gas trapped inside. It was the beginning of modern fracking.

"It was a good well, cost $600,000 or $700,000," Mr. Steinsberger said, walking over the pad to the chain-link fence that surrounds the well. A sign identifies it as the S. H. Griffin Estate 4.

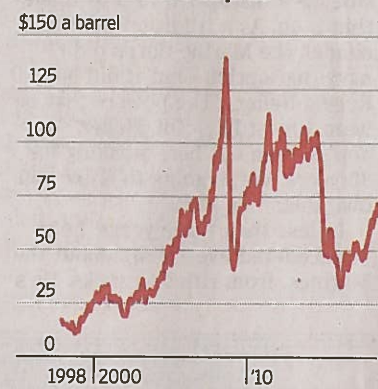
Today, most wells drilled in the U.S. use some variation of Mr. Steinsberger's fracking technique. It has unleashed an unimaginable wealth of natural gas, gas liquids and crude oil, turning the U.S. from an energy pauper into a muscular exporter. It also started an often acrimonious environmental debate about the potential impacts and trade-offs of fracking.

"It is one of the most extraordinarily important, disruptive, technologically driven changes in the history of energy," said Ed Morse, global head of commodity research at Citigroup. "It was revolutionary for the U.S. economy and it was revolutionary geopolitically."

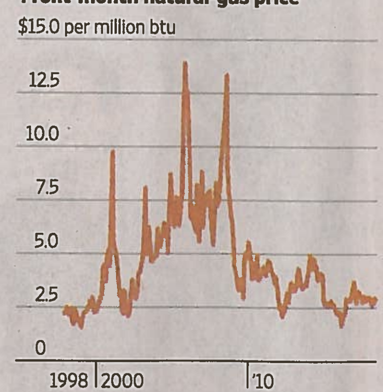
Mr. Steinsberger's modest experiment demonstrated that the oil and gas industry had the tools to fracture the rocks where fossil fuels were slowly baked over the millennia. A huge trove of natural gas was accessible at an economical cost.

It was such a novel idea that it spread slowly at first, as doubters couldn't believe that anyone could successfully tap the source rocks.

Front-month crude-oil price



Front-month natural-gas price



Source: WSJ Market Data Group
THE WALL STREET JOURNAL.

After a few years, more companies began to copy the wells drilled by Mr. Steinsberger's employer, Mitchell Energy, the firm founded by the late George P. Mitchell.

It started in the Barnett Shale. Then other gas-bearing shales were discovered. The Marcellus Shale in Appalachia turned out to be larger and more fecund than the Barnett.

In 2008, more than a decade after Mr. Steinsberger's well, the industry made another quantum leap: Not only could fracking liberate small natural gas molecules from rocks, it also worked on the longer hydrocarbon chains that make up crude oil. Companies such as EOG Resources Inc. began to drill and frack shales bearing crude oil and natural gas liquids in North Dakota and Texas. The technique has since spread to other countries such as Argentina.

The proliferation of oil and gas production transformed the U.S. energy landscape. A looming dearth of natural gas had led companies to build import terminals. Now there is so much gas the U.S. exports the fuel around the world.

The low-cost fuel has become the leading source of power generation in the U.S. Its rise has reshaped electricity markets, leading to the closure of more than 200 coal plants, as well as a number of nuclear plants. The Trump administration's current proposal to subsidize coal and nuclear plants is an indirect result of fracking.

The impact on oil markets might be, if anything, more significant. U.S. oil production had fallen persistently for years, dropping below five million barrels a day. And then: fracking. This year, it hit a new all-time high, reaching 10.9 million barrels a day in June. It is now the world's largest producer of crude and other valuable petroleum liquids, ahead of Russia and Saudi Arabia.

The surge has weakened the Organization of the Petroleum Exporting Countries. Facing a grow-

BUSINESS

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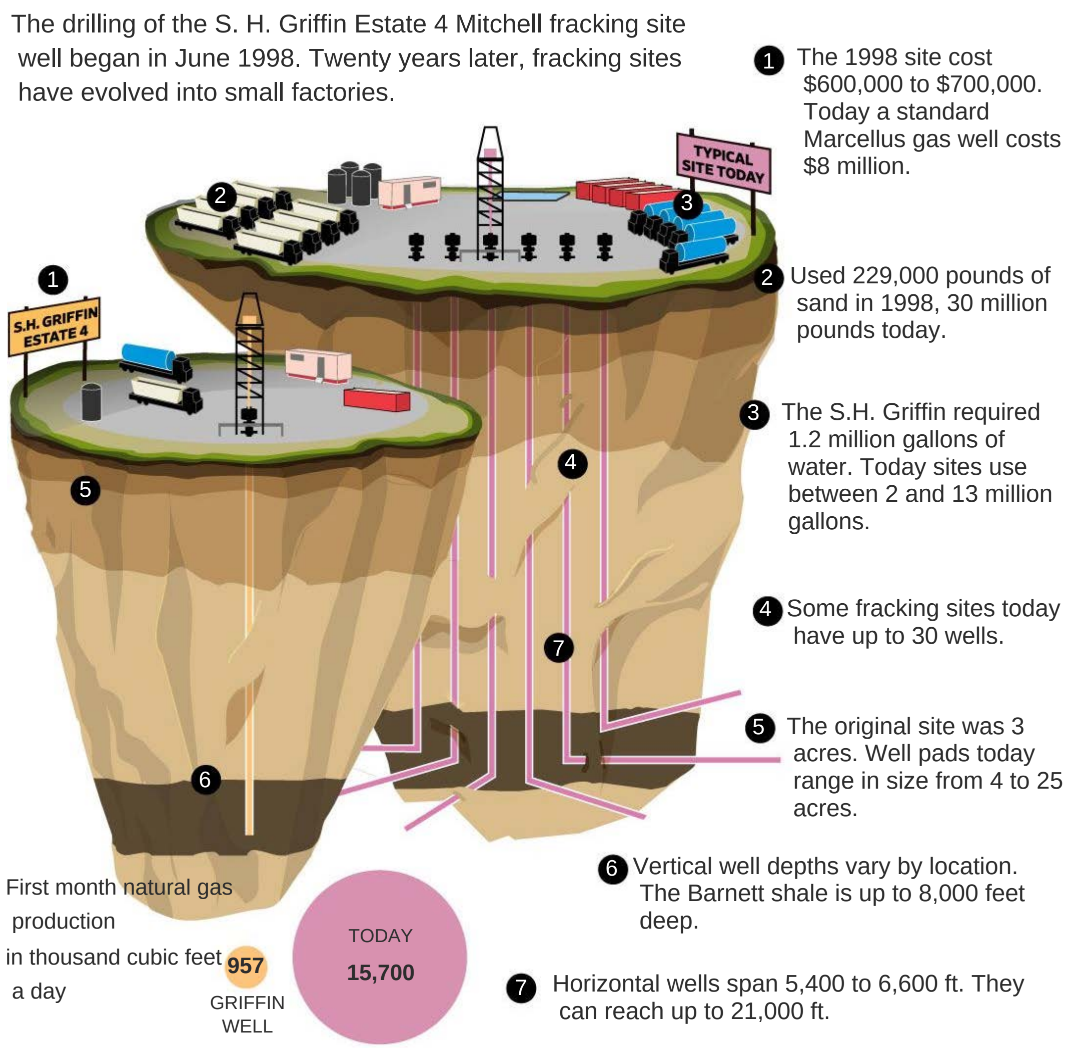

Sources: U.S. Energy Information Administration; Vengosh (water); Cabot Oil & Gas, Range Resources (cost); The Railroad Commission of Texas.
Graphic by Hanna Sender/The Wall Street Journal.

By *Russell Gold*

June 29, 2018 7:00 a.m. ET

210 COMMENTS

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Nick Steinsberger pulled off the first commercially successful fracking well 20 years ago this month. He revisited that well in early June. PHOTO: BRANDON THIBODEAUX FOR THE WALL STREET JOURNAL

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Created with Highcharts 6.0.4U.S. Crude-oil productionSource: Joint Organisations Data Initiative

Created with Highcharts 6.0.4RussiaSaudi ArabiaU.S.200220032004200520062007200820092010201120122013201420152016201720183456789101112

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Modern fracking operations are significantly larger and more involved. Here, line boss David Cantu checks the performance of pumping units at a Cudd Energy fracking operation on a Fasken Oil and Ranch well in Midland, Texas, in May. PHOTO: JAMES DURBIN FOR THE WALL STREET JOURNAL

The surge has weakened the Organization of the Petroleum Exporting Countries. Facing a growing supply of oil from the U.S., the group stumbled and fought over what to do. It unsuccessfully tried to crush frackers by ramping up production in 2014 to drive down the price of oil, before making its peace with them. Last week, the cartel's members coordinated with Russia to produce more barrels to prevent oil prices from rising further. Shale output was outside of their control.

The U.S. emerged as a newly confident energy powerhouse. It was no longer fearful that an embargo could maim its economy. This attitude was reflected in a more aggressive foreign policy, as shown by its willingness to take a tough negotiating posture with Iran.

"The fracking boom was the biggest energy story around the world. But it was also the biggest geopolitical story and the biggest environmental story," said Michael Webber, deputy director of the Energy Institute at The University of Texas at Austin.

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The proliferation of natural gas, displacing coal, helped the U.S. lower its overall greenhouse gas emissions by 13.4% in the last decade, while growing its gross domestic product, according to BP PLC's Statistical Review of World Energy.

While fracking has produced environment benefits at a global scale, it has created local problems. Dust, noise, truck traffic and emissions from diesel engines turned rural regions into industrial zones during periods of peak development.

The headlong rush to drill and frack meant that the industry raced out in front of state regulators. Concerns arose about fracking's impact on water and the impact of methane gases leakage on the climate. Eventually, federal and state regulators responded with increasingly sophisticated rules. And the industry adopted some voluntary measures as well.

Fracking has split the environmental movement. Some environmentalists opposed fracking entirely; others recognized its potential benefits and have worked to minimize its negative impacts.

Created with Highcharts 6.0.4Front-month natural-gas priceSource: WSJ Market Data Group

Created with Highcharts 6.0.41998199920002001200220032004200520062

Fred Krupp, president of the Environmental Defense Fund, praised natural gas for helping clean up local air pollution, lower greenhouse gas emissions and reduce electricity costs. "The abundance of natural gas has helped, but it is important to work to make it as clean as it can be," he said.

Meanwhile, fracking continues to evolve. Supersized fracks have become commonplace.

Fracking uses grains of sand to prop open the newly formed cracks to allow gas or oil to flow out. While Mr. Steinsberger's well required 229,000 pounds of sand, a large contemporary well might require 30 million pounds of sand. The amount of water needed has increased as well.

The S. H. Griffin well has continued to produce gas for two decades. Over the years, more than 2.6 billion cubic feet have flowed out, worth some $8 million at today's prices. A new well with a supersized frack can produce as much in a day as the original could in two months.

The proliferation of large wells has kept gas below $4 per million British thermal units since December 2016, after topping $10 in 2008. Mr. Steinsberger, who still oversees eight to ten fracks a year, doesn't see that changing for a long time.

"One day, there might be lasers shooting at the rock" thousands of feet underfoot, he said. "I can't predict that. But I can tell you natural gas prices will be low for the rest of our lives."

Rising oil prices are not good for consumers, or for President Trump's administration. The Wall Street Journal's Gerald F. Seib explains the rise in oil prices. Photo: Getty

Write to Russell Gold at russell.gold@wsj.com

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