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LITE geology

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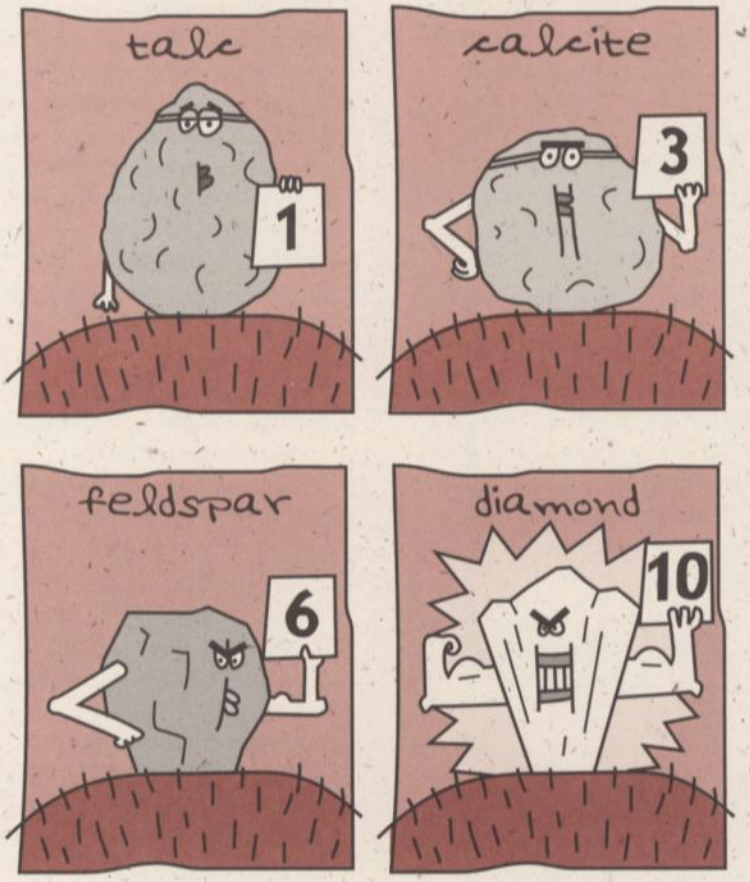
A publication for educators and the public–contemporary geological topics, issues and events



hardness scale

This Issue

Earth Briefs–The great Canadian Diamond rush

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Earth Briefs

Canadian prospecting finally pays off

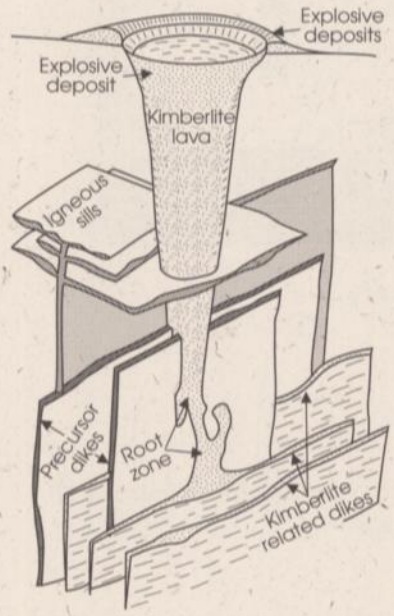
Over the last two decades, the Northwest Territories of Canada have experienced a rush of prospectors who endured the hardships of isolation, hordes of insects, and arctic climate along with fierce competition while exploring for something more elusive and rare than gold: Diamonds!

Economic deposits of gem-quality diamonds have been found in kimberlite rocks underneath lakes about 180 miles northeast of Yellowknife in the Northwest Territories and only 60 miles south of the Arctic Circle. Kimberlites are unusual volcanic rocks that are the source of most of the world's diamonds. This rock originates deep in the mantle where the diamonds are formed. As it erupts, it carries the diamonds to the surface. Kimberlitic magma typically expands during eruption, breaking up rock in its path as it blows out through the crust leaving deep, carrot- (not carat!) shaped pipes that tend to occur in small clusters. Lakes can form in the surface depressions produced by kimberlite eruptions. One of the clues to the Canadian diamond discovery was the recognition of a group of round lakes that overlie kimberlite pipes; another clue was the presence of indicator minerals and diamonds that had been eroded and carried by glaciers and weathered into the streams of the region.

Contributing to the diamond's rarity is the fact that very special physical conditions are necessary for them to survive the journey of the kimberlitic magma to the Earth's surface. Ascent must be rapid, lasting only a few days or weeks, or the diamonds become chemically unstable and convert to graphite. Of the 4,000 known kimberlite pipes on the planet, 90% are not diamondiferous; most of the remaining pipes do not have economic concentrations of diamonds. The lowest grade of kimberlite material that is considered economic is 0.6 carat/ton with a high proportion of gem-quality diamonds.

Certain types of garnets, chromite, ilmenite, and chrome-bearing diopside are found in both diamond-bearing and diamond-free kimberlite rocks. However, the conditions under which diamonds form yield indicator minerals with characteristic chemical signatures. Not until the 1980s were the slight compositional differences of the diamond-indicator minerals understood. For instance, a garnet that is lower in calcium and higher in chrome was identified; chromite with more than 62.5% chrome was also tagged as a diamond indicator mineral. Interestingly, ilmenite with a high percentage of oxidized iron (Fe^{3+}) is considered a negative indicator for the occurrence of diamonds, perhaps signaling an environment that would have oxidized the diamonds into carbon dioxide (CO_2).

Two persistent prospectors, Charles Fipke and Stuart Blusson, armed with this new understanding of indicator minerals spent ten long years tracing them back along the Mackenzie River Valley to the kimberlite pipes in the Lac de Gras region, where these deposits are now being developed by several mining interests. Fipke and Blusson had reasoned correctly that since diamonds are found on other continents where the Earth's crust and upper mantle are old (greater than 2.5 billion years) and relatively cool, they should be present in northern Canada where some of the Earth's oldest rocks have been found. Their 10-year ordeal to find the diamond pipes is a monument to faith in a geologic theory and stubborn persistence. Canada's first diamond mine, Ekati, is a partnership between the two successful prospectors (each holding a 10% share), BHP Diamonds (controlling 51%), and Dia Met Minerals (holding the remaining 29%). In the past few years, more than 230 companies have staked claims over a 75,000 square mile area. The Canadian diamond rush has sparked a thrilling level of optimism within the government, stock market, and business community.



Cross-section of a kimberlite pipe system

Will this new glut of gem-quality diamonds affect world prices, making them less expensive to consumers? Probably not. Most of the world's rough diamond supply is controlled by the De Beers company's Central Selling Organization. This diamond cartel regulates the supply and prices on the world's diamond market. The former chairman of the De Beers organization is often quoted on his view of the diamond cartel "Whether this measure of control amounts to a monopoly, I would not know, but if it does, it is certainly a monopoly of a most unusual kind. There is no one concerned with diamonds, whether as producer, dealer, cutter, jeweler or customer, who does not benefit from it."

So how profitable is a diamond mine? Ekati, the first diamond mine developed in the Lac de Gras area, is expected to generate an average revenue of about $500 million (Canadian dollars) per year during its 17-year life. Capital costs to develop Ekati are projected to be about $900 million. Additional mines are likely.

Rocks older than 2.5 billion years also occur in Wyoming and in the subsurface of northernmost Colorado. This is the old Archean nucleus to which the younger basement rocks of Colorado and New Mexico were accreted by plate tectonic and magmatic processes. More than 40 diamond-bearing kimberlite pipes have been found in the Colorado-Wyoming State-Line district. Radiometric dating indicates that the pipes range in age from about 620 to 400 million years ago. Testing of kimberlite pipes in this district recovered 120,000 diamonds, including a 28.3-carat gem-quality diamond from the Kelsey Lake mine. Indicator minerals have been found over a 1,000-square-mile area of the

Green River Basin in southwestern Wyoming and prospecting is active in other areas of Wyoming.

Unfortunately, the basement rocks in New Mexico range in age from 1.7 to 1.1 billion years and are generally considered too young for the occurrence of diamonds even though kimberlite pipes have been reported on the Colorado Plateau and in the Raton area. A tantalizing but unconfirmed report of a diamond found in dirt from a well near Tucumcari was published in *Southwestern Mines* in 1909.

—Story by S. Welch, N. Dunbar, and C. Chapin

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Have You Ever Wondered...

. . .How much money does New Mexico receive from mining and oil and gas production?

Dr. Charles Chapin
NMBMMR Director and State Geologist

Facts and figures on money and taxes can be deadly boring... especially taxes. But they are also among the most important subjects we deal with. Understanding our state's budget, i.e., where does the money come from and how is it spent, is particularly difficult. The information is reported in different ways by different groups and agencies in various places and for differing time periods. *Lite Geology* is supposed to be a fun-to-read, easy to understand publication for school science teachers, students, and the general public. Am I crazy to attempt this subject here? Well, let's see if I can do it.

Where are the mines and oil and gas fields?

What if you had a chance to carve out a state the size and shape of New Mexico anywhere you wanted in the United States. Being familiar with the importance of natural resource revenues to the funding of state government, you decide to put down your state "cookie cutter" where you can capture the maximum amount of oil and gas and other mineral resources. Lean back and think a minute. Ready? Well you could not find a better location than that already occupied by the Land of Enchantment!

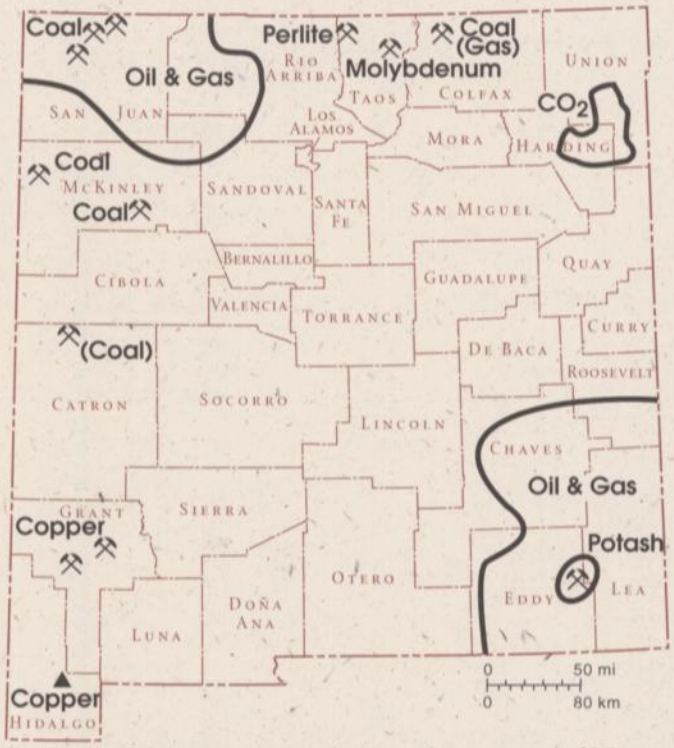

Figure 1—Major energy and mineral resources of New Mexico. Those in parentheses are not yet in production. The triangle in Hidalgo County is the Playas copper smelter of Phelps Dodge.

Figure 1 shows the distribution of major energy and mineral resources in New Mexico. Move the state boundaries a little to the west and you lose the rich oil and gas deposits of southeastern New Mexico, plus the Carlsbad potash district (from which 85% of domestic potash comes), plus

the Bravo Dome carbon-dioxide field in northeastern New Mexico (with the largest CO_2 reserves in the U.S.). Move the state boundaries one county to the south and you lose major coal production in the Farmington and Raton areas, plus the world's largest producing coalbed methane (natural gas) field and major conventional gas and oil of the San Juan basin, plus major molybdenum deposits near Questa and perlite deposits at No Agua that make New Mexico number one in the U.S. in perlite (expanded, light-weight, volcanic glass) production. Move the state boundaries to the east...well, you get the idea...any way you move them, you lose!

How much do the mines and oil and gas fields produce in a year...and what is it worth?

In 1997, New Mexico produced energy and mineral commodities worth approximately $6.7 billion. The pie diagram of Figure 2 shows the relative proportions of the $6.7 billion contributed by the major commodities. Table 1 gives the details. You may be surprised to learn that natural gas was by far the largest contributor with a value 2.5 times that of oil and exceeding the value of all the other mineral commodities combined.

Approximately 60% of the natural gas is produced in the San Juan basin of northwestern New Mexico (mainly

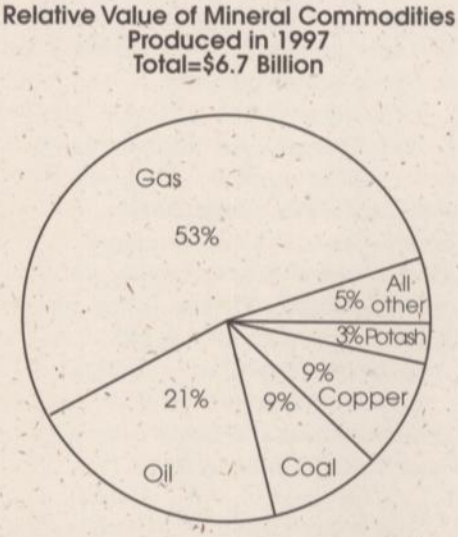

Figure 2—Total production and relative value of mineral commodities produced in New Mexico in 1997.

Table 1—New Mexico energy and mineral production 1997

COMMODITY	VALUE	PRODUCTION	RANK OF PRODUCTION IN U.S.	RANK OF RESERVES IN U.S.
Gas	$3.5 billion	1.6 trillion ft^3	3	2
Oil	$1.4 billion	72.9 million bbls	7	4
Copper	$598.8 million	573.6 million lbs	3	—
Sulfuric Acid	$2.1 million	1.1 million short tons	—	—
Coal	$620.1 million	26.8 million short tons	13	10
Potash	$179.9 million	1.64 million short tons of product	1	1
Aggregate	$107.9 million	12.5 million short tons	—	—
Silver	$2.5 million	468,742 oz	10	—
Gold	$10.5 million	28,709 oz	10	—
CO_2	$52.0 million	143 billion ft^3	2	1
Industrial minerals	$209.2 million	31.8 million short tons	perlite 1 pumice 2	1 1
Uranium	$2.2 million	216,393 lbs U_3O_8	6	2
Molybdenum	$25.1 million	8.3 million lbs	6	—
TOTAL	**$6.7 billion**	—	—	—

San Juan and Rio Arriba counties) with the remainder coming from the Permian basin of southeastern New Mexico (principally Lea, Eddy, and Chaves counties). A drilling program to develop the coalbed methane in the Raton basin of northeastern New Mexico (Colfax County) has been announced .

Table 1 also shows how New Mexico's production of each commodity compared with production from other states. Note that we are first in production of potash and perlite, second in carbon dioxide (CO_2) and pumice, third in natural gas and copper, seventh in oil, etc. New Mexico is in the **big** leagues of energy and mineral production! The last column of Table 1 shows how we rank in reserves (deposits in the ground that can be produced at a profit in the future). We move up from third in current production to second in reserves of natural gas, from seventh to fourth in oil, from second to first in carbon dioxide, and from sixth to second in uranium. In other words, New Mexico will be a major source of the nation's energy and minerals for decades to come! Not only is New Mexico blessed with a multi-billion dollar energy and mineral industry, the production is highly diversified. If one segment of the industry slips into recession, as have molybdenum, copper, and oil, in recent years, production of other commodities can pick up some of the slack.

How does the energy and mineral production benefit New Mexico...and me?

One of the biggest benefits of the energy and mineral industries to New Mexico is high-paying jobs in rural counties where employment opportunities are limited. Table 2 lists the number of employees in each segment of these industries in New Mexico and their average wages. People employed directly in the energy and mineral industries totaled 18,091 in 1997 with a total payroll of $653 million. Average wages varied between about $34,000 and $51,000; benefits, such as health care, retirement, and other benefits, would add another 30%. Mining pays the highest wages of any industry in the U.S. with a national average of $45,000. What would be the impact in your community if there were 2,000 miners earning $45,000 a year?

Another major benefit of the energy and mineral industries is the revenue paid to school districts, cities, counties, and the state in various kinds of taxes and royalties (the State's share of the value of

Table 2—Economic impact of New Mexico energy and mineral production 1997 (*1995 figures, CP = Coproduct of Copper Mining; NA = Not Available)

COMMODITY	PAYROLL (million)	EMPLOYEES	AVERAGE EARNINGS	NM ROYALTIES AND TAXES ON PRODUCTION (million)
Gas and Oil	$352*	10,239*	$34,355*	$664
Copper	$106.8	2,707	$44,972	$4.6
Coal	$91.0	1,695	$50,856	$34.3
Potash	$72.1	1,519	$45,667	$2.5
Aggregate		1,002	?	$0.54
Silver and Gold	CP	CP	CP	$0.12
CO_2	$0.63*	14*	$45,000	$1.8*
Industrial minerals	$14.9	550	$35,556	$0.09
Uranium	$1.7	56	$42,647	NA
Molybdenum	$14.5	309	$39,130	NA
TOTAL	**$653.63**	**18,091**	**ave. $42,273**	**$707.95**

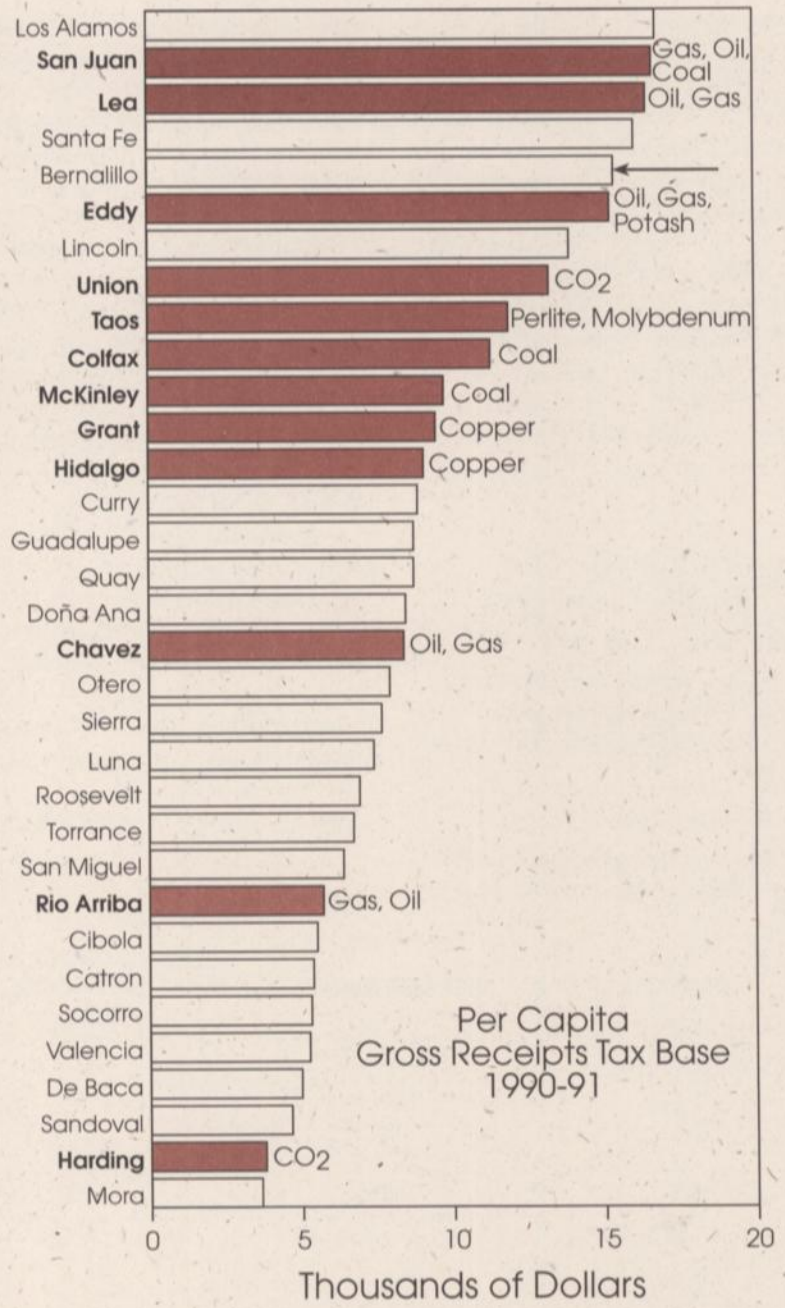

Figure 3—Per capita gross receipts tax base of New Mexico counties in 1991 (Bureau of Business and Economic Research, 1994). Counties with major energy and mineral resource production are listed in bold type and the corresponding bar is shaded. The type of production is labeled. The arrow shows the position of Bernalillo County.

minerals produced on a property). The right-hand column in Table 2 lists the royalties and taxes on production paid directly to the State in 1997. Natural gas and oil pay the lion's share of direct taxes and royalties with coal next in line. Coal sold to generate electricity also generates gross receipts (sales) taxes which added an estimated $20 million to State revenue in 1997. We will return to taxes and royalties in a later section and see their impact on the State budget and local communities.

Let us look first at the impact the energy and mineral industries have on the counties where you live. Figure 3 is a histogram (bar graph) from a 1994 report by the Bureau of Business and Economic Research at the University of New Mexico. Figure 3 shows how the per capita (per person) gross receipts tax base varies among New Mexico counties. The gross receipts tax is similar to a sales tax but is added to the price and remitted to the State by the seller; it is also more broadly based, applying to services such as medical care, consulting, leasing, etc. Note how the counties with major energy or mineral production (shaded) are clustered at the high end of the chart. Energy and mineral producers pay gross receipts taxes on the equipment and supplies they purchase and collect gross receipts taxes on the commodities they sell; their highly paid employees also have more money to spend. Other counties at the high end of the chart are those with a national laboratory (Los Alamos, Bernalillo), a concentration of retail and manufacturing businesses (Bernalillo), or ski areas and tourist destinations (Santa Fe, Lincoln and Taos). The bold arrow points to Bernalillo County, which

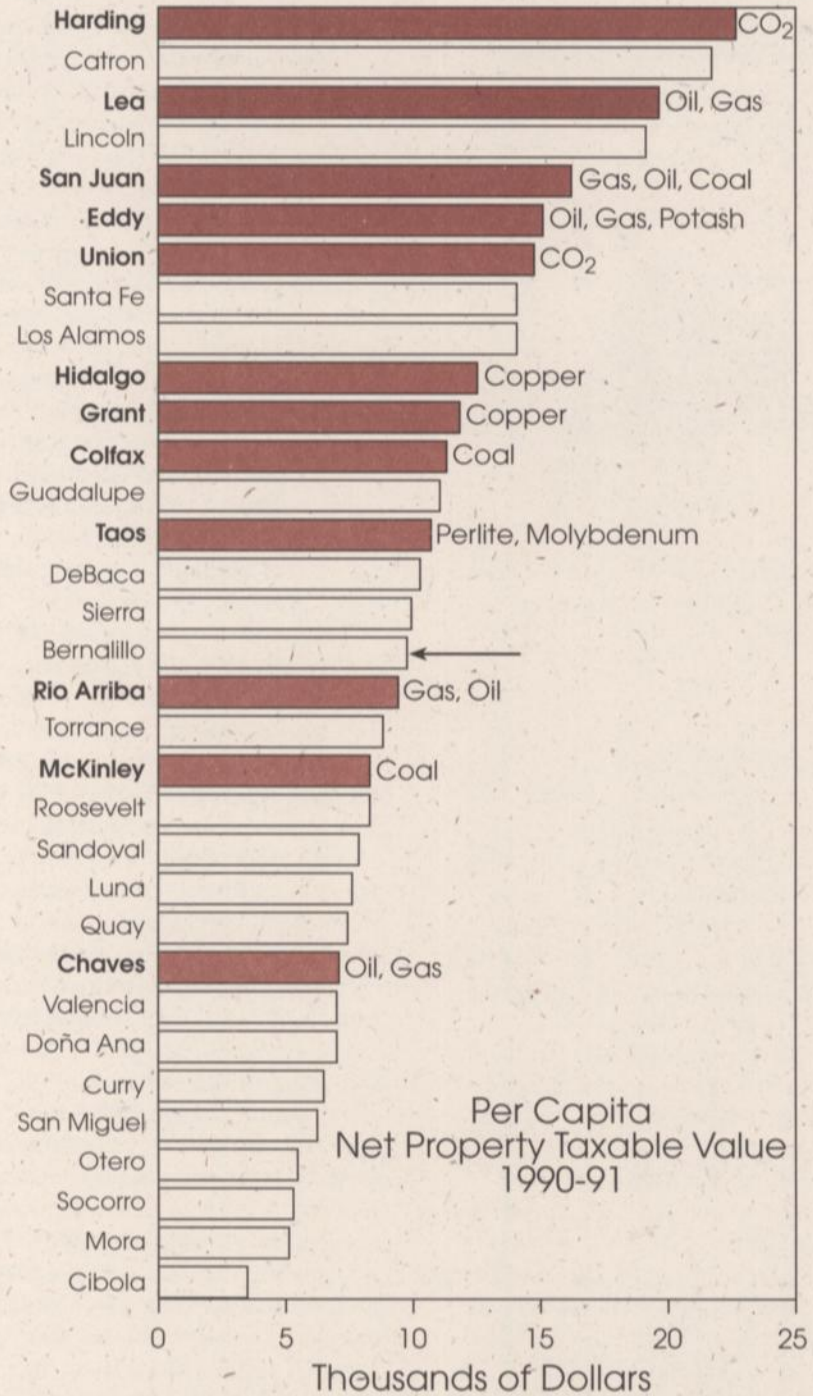

Figure 4—Per capita net property taxable value of New Mexico counties in 1991 (Bureau of Business and Economic Research, 1994). Counties with major energy and mineral production are listed in bold type and the corresponding bar is shaded. The type of production is labeled. The arrow shows the position of Bernalillo County.

contains Albuquerque, the major business center of the State. The higher the gross receipts tax base the more money a county has to support its government and pay for services. Approximately 20% of gross receipts taxes is returned to the community, the rest goes to the State General Fund, which pays the State's annual operating expenses.

Cities, counties, and school districts also rely heavily on property taxes to fund their operations. Figure 4 is another histogram from the same report by the Bureau of Business and Economic Research that shows the variation in per capita net property taxable value among New Mexico counties. Net taxable value is one-third of assessed property value less exemptions and deductions. Again, the counties with major energy or mineral production are holding up the high side of the chart. This is because energy and mineral producers pay property taxes on land, equipment, and the value of their production; their highly paid employees also tend to own more property. In the Silver City area (Grant County), copper mining contributes about three-quarters of the Cobre Consolidated School District's taxable property value. Reduced copper production and layoffs caused by low copper prices will probably require an increase in residential property taxes this year.

Where does your county fit on Figures 3 and 4? I live in Socorro County, which has no energy production, only one small perlite mine, no ski area or national laboratory, very modest shopping facilities, and only about 15,000 people. On which end of the chart would you look for Socorro County?

What about the State's Annual Operating (General Fund) Budget?

Figure 5 shows the revenue the state received during fiscal year 1997, which ended June 30, 1997. The two biggest sources of revenue are 1) gross receipts (sales) taxes (36.3%) and 2) personal and corporate income taxes (28.2%). The energy and mineral industries are major contributors to both categories. The eighteen thousand people employed in these industries and earning average wages ranging from $34,000 to $51,000 pump a lot of dollars into local communities. Economists estimate that each new dollar brought into a community is multiplied three to six times as it circulates. If the 5% gross receipts tax is paid each time, the state and the community derive considerable revenue. Those same high-paid employees also pay state income tax, adding to the other major slice of the pie.

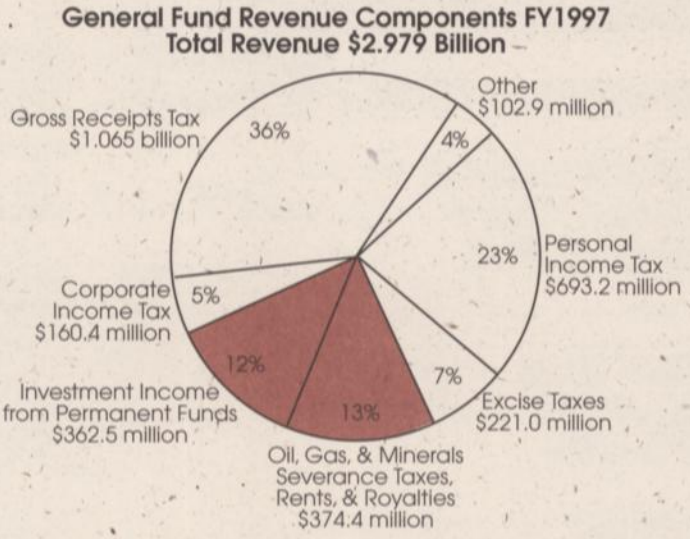

Figure 5—General Fund revenue components for fiscal year 97. Compiled from sources listed at the end of this article.

Mining and petroleum companies also pay gross receipts taxes on their purchases of goods and services. Copper mines, for example, consume large quantities of diesel fuel, electricity, chemical reagents, and explosives; they also purchase lots of equipment, some of which are very expensive (a single 300-ton truck costs about $2.5 million; its tires cost $22,000 each). When purchased out-of-state, a compensating tax (5%) is charged, which takes the place of the gross receipts tax. The companies also pay corporate income taxes, which range up to 7.6% on income over $1,000,000. Thus, the two largest slices of New Mexico's annual revenue pie contain major contributions from the energy and mineral industries.

Two other large slices of the General Fund revenue pie (shaded in Figure 5) are "Investment Income from Permanent Funds" and "Severance Taxes, Rents and Royalties." They are interrelated and relatively obscure slices of the pie, but together they comprise approximately a quarter of the revenue. I think you will find them interesting.

The oldest of the permanent funds is the Land Grant Permanent Fund. At statehood in 1912, New Mexico received lands totaling about 12% of the state under the Enabling Act. The revenues from these lands go into a permanent fund, which now totals approximately $7.4 billion. Investment earnings on the Land Grant Permanent Fund go to the General Fund where they are used to fund education and several special institutions and structures, such as the School for the Deaf, the State Penitentiary, water reservoirs, etc. Only the earnings from investments, not the corpus (body) of the fund, are distributed to the beneficiaries. Each parcel of state trust land is assigned to a specific beneficiary institution or group of institutions. Approximately three-quarters of all state surface and mineral acreage is assigned to public schools; in FY 1990 they received 82.6% of the income from the Land Grant Permanent Fund.

The second permanent fund is the Severance Tax Permanent Fund, which was started by the Legislature in 1973. Severance taxes are monies the State collects from producers for the right of severing minerals from the ground. Some of the severance tax income goes to a Severance Tax Bonding Fund that is used to retire debt on bonds issued to finance construction of public facilities. The remainder is deposited in the Severance Tax Permanent Fund, which now contains $3.7 billion; investment earnings from this fund go to the State General Fund where they are used mainly to support education.

Royalties are fees companies and individuals pay to the landowner for the privilege of removing energy or mineral commodities from the ground. The amount charged depends on the commodity and who owns the mineral rights. Ownership of New Mexico's 77.8 million surface acres is 44% Private, 34% Federal, 12% State, and 10% Indian Trust

Lands. But the owner of the surface does not always own the mineral rights. For example, the State Land Office administers 13.1 million acres of mineral rights but only 9.2 million acres of surface. How New Mexico's lands were divided up is an interesting story, perhaps for a future article. Two-thirds of natural gas production and 40.9% of oil production occurs on Federal lands in New Mexico. New Mexico receives 50% of the leasing revenue from Federal lands minus administrative costs. Of the 50% retained by the Federal government, 40% goes into the Reclamation Fund for water projects and the remaining 10% goes to the U.S. Treasury. New Mexico's oil and gas production comprises approximately 30% of Federal on-shore leasing in the United States. In 1997, Wyoming and New Mexico together received nearly 70% of the revenue distributed to states from oil and gas leasing on Federal lands. New Mexico received $63,161,723 from the Federal Government for its share of leases and royalties paid to the feds during the first half of 1999.

New Mexico's two permanent funds now total approximately $11 billion. Together they constitute the third largest endowment of its kind in the United States. In fiscal year 1997, $362.5 million, or 12% of the State's General Fund budget was derived from investment earnings of the two permanent funds. Without this income, state income taxes would have been about $600 per year higher for each taxpayer.

If your head is "swimming" a bit from all these facts and figures, you are not alone! I hope you have found this article useful in gaining a better understanding of where the money comes from and the vital role our energy and mineral industries play in supporting education and other State services. The next time you pass a petroleum pump jack or a mining operation on your travels, smile and say, "Hey, I know about you guys!"

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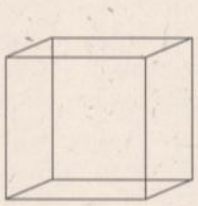
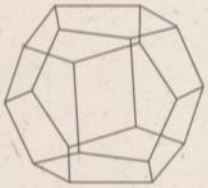
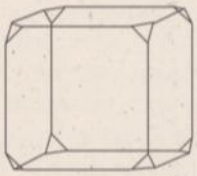
New Mexico's Most WANTED MINERALS



PYRITE

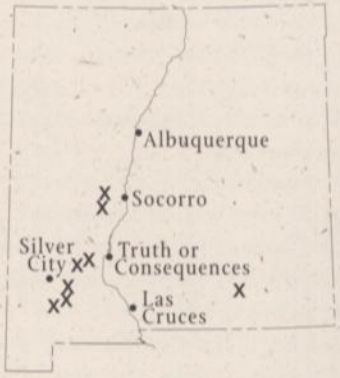
DESCRIPTION: Watch for pyrite to resemble gold or chalcopyite but with a brassy tint. Powdered pyrite is greenish to brownish black. It has a metallic luster but tends to rust in the presence of water and oxygen. It has an indistinct cleavage and tends to form cube-shaped crystals and less commonly, octahedral and pyritohedral shapes. It can also be massive, granular, radiating, reniform, globular, or stalactitic. Often the crystals will be striated. It gets its name from the Greek, *pyr*-fire, alluding to the fact it sparks when struck with steel. It has a hardness of 6 to 6.5, so it will scratch glass. Chemical name: Iron sulfide. Formula: FeS_2

WANTED FOR: Pyrite is usually not wanted for any industrial use, other than as a source for sulfuric acid (Pyrite + water makes sulfuric acid, naturally). It is prized by collectors for its color, luster and form.

HIDEOUT: Pyrite is the most common of the sulfide minerals. It can be found in many types of ore deposits and dark-colored sedimentary rocks.

LAST SEEN AT LARGE: It is present in most mining districts in the state. Pyrite specimens of museum quality have been found at:

Grant County: Chino, Tyrone, Empire and Continental mines
Socorro County: Kelly, Linchburg mines
Sierra County: Brush Heap and Copper Flat mines
Chaves County: Bosque Draw



ALIASES: Fool's Gold

Sources for Earth Science Information

Teachers!
Attend a free energy workshop
October 7-8, 1999
Roswell, NM

The NEED (National Energy Education Development Project) has a mission to promote an energy conscious and educated society by creating an effective network of students, educators, business, government, and community leaders to design and deliver objective, multi-sided energy education programs. This two-day workshop includes classroom activities and field trips. Funding may be available for substitutes and travel. Contact:

Mary Spruill
State Program Director
NEED Project
102 Elden St., Suite 15
Herndon, VA 20170
(703) 471-6263; need@erols.com

The contact in New Mexico is Gerry Harrington at (505) 625-0144.

Mark your calendars now for
Earth Science Week
October 10-16, 1999

Make plans to join the celebration and help students discover the Earth Sciences. Spread the message that Earth Science is all around us and encourage stewardship of the Earth through an understanding of Earth processes. To request your Earth Science Week Information Kit, contact:

Earth Science Week
American Geological Institute
4220 King Street
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