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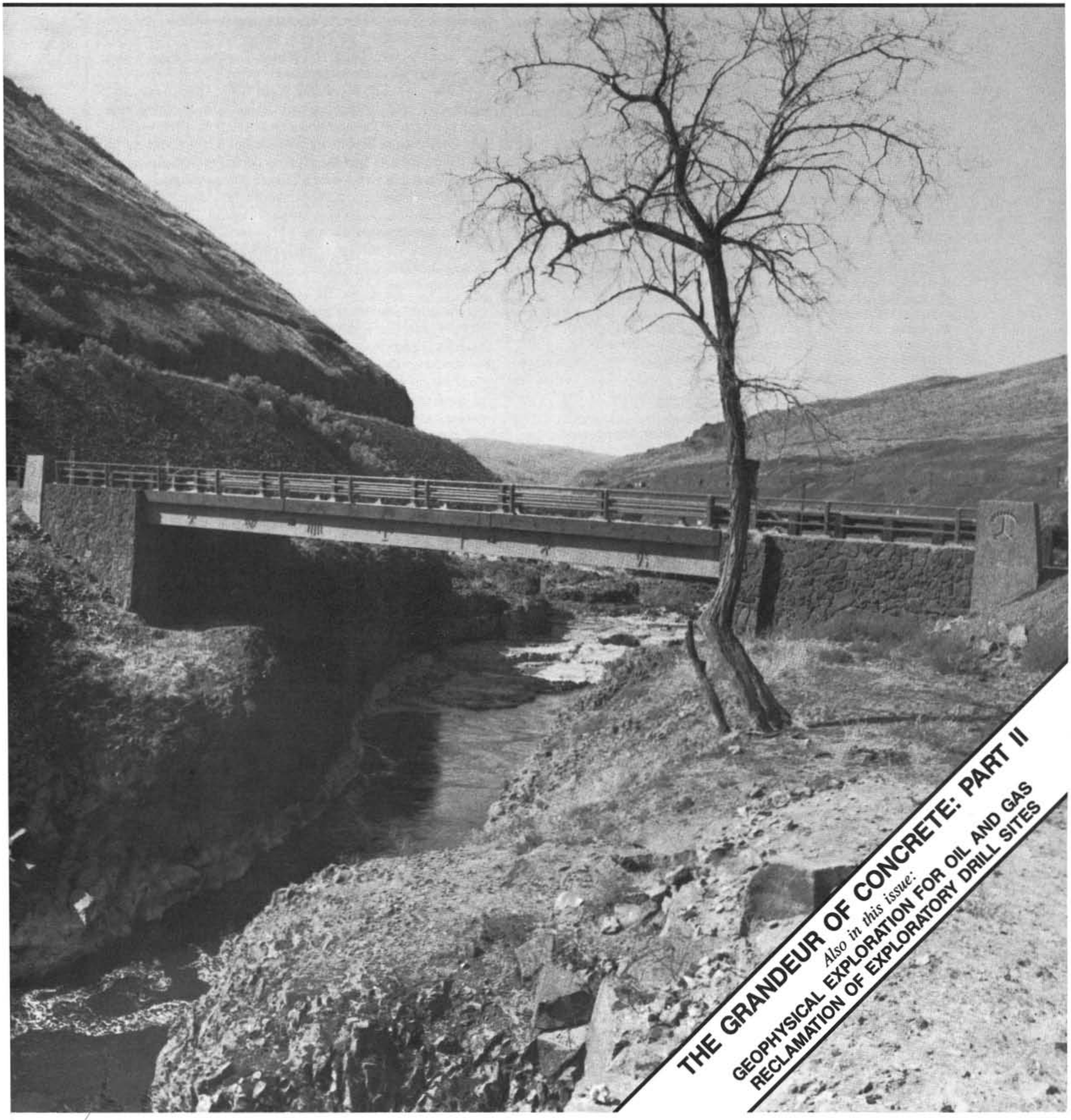

THE GRANDEUR OF CONCRETE: PART II

Also in this issue:

GEOPHYSICAL EXPLORATION FOR OIL AND GAS

RECLAMATION OF EXPLORATORY DRILL SITES

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment, a file copy on 5¼-in. diskette may be submitted in addition to the paper copies. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors,* 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Sherars Bridge in Wasco County, Oregon, near Tygh Valley and Maupin, where State Highway 216 crosses the fast-flowing Deschutes River. At this point, the river has cut a channel 80 ft deep and barely 40 ft wide into volcanic rock, offering a crossing point for an ancient Indian trail. Peter Skene Ogden arrived here in 1826 and reported finding a footbridge. From 1860 on, a bridge was maintained here for pioneer wagon trains.

The relatively simple prestressed-concrete slab construction received special architectural treatment because of the historic and scenic significance of the locality. It is the site of traditional Indian fishing camps and part of the Deschutes River Scenic Waterway. Designs based on Indian pictographs carved on a nearby cliff were formed into the sides of the exterior deck slabs and the pedestrian rail posts. The acceptability of the designs was cleared with the Council of the Confederated Tribes of the Warm Springs. The concrete abutments and wing walls were faced with native stone, and the metal bridge rail was painted a bronze color, so that the structure would blend in with its surroundings. Photo courtesy of OCAPA.

Position Announcements
Oregon Department of Geology and Mineral Industries

Geologist IV — Senior Geologist

Full-time, senior-level, permanent position, available August 1, 1989. Starting salary approximately $2,600-2,900 per month plus benefits. Location is Grants Pass, Oregon.

Graduate degree or equivalent is required, as well as a minimum of five years of progressively responsible experience in conducting and managing field projects, preferably including economic geology and geologic mapping in volcanic, Tertiary marine sedimentary West Coast, and/or pre-Tertiary terranes. Provinces include Basin and Range, Cascade Range, Coast Range, and Klamath Mountains.

Duties include supervising small field office; designing, supervising, and coordinating multi-year economic-geology and geologic-map projects; conducting active field work; writing clear and concise reports for publication; active reviewing of geologic aspects of land use planning documents and processes; and dealing effectively with a diverse public. Emphasis is on geologic mapping and geologic reports for publication. Position requires close coordination with Federal, State, university, and industry counterparts.

Deadline for receipt of the completed application packet is July 1, 1989.

Geologist III — Field Geologist

Full-time, permanent position, available September 1, 1989. Starting salary approximately $2,200-2,500 per month plus benefits. Location is Grants Pass, Oregon.

Graduate degree or equivalent required, as well as a minimum of four years of progressively responsible experience in conducting field projects, preferably including economic geology and geologic mapping in volcanic, Tertiary marine sedimentary West Coast, and/or pre-Tertiary terranes. Provinces include Basin and Range, Cascade Range, Coast Range, and Klamath Mountains.

Duties include designing, conducting, and coordinating economic-geology and geologic-map projects; conducting active field work; writing clear and concise reports for publication; participating in the geologic aspects of land use planning; and dealing effectively with a diverse public. Emphasis is on geologic mapping and geologic reports for publication. Position requires close coordination with Federal, State, university, and industry counterparts.

Deadline for receipt of the completed application packet is August 1, 1989.

Applicants for either position must submit resume and three professional references, as well as their requests for the necessary application packet to Oregon Department of Geology and Mineral Industries, 1400 SW Fifth Avenue, Room 910, Portland, Oregon 97201-5528. Phone (503) 229-5580.

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CONTENTS

The grandeur of concrete: Part II

by Don Dupras, Geologist, California Division of Mines and Geology

This article is the second of a two-part series describing how concrete is made and how important it is in our lives. The series first appeared in the January and February 1989 issues of *California Geology* and is reprinted here by permission because we believe it will be of interest to our readers. Part II presents principles of concrete making and current developments in concrete technology that enable architects and engineers to design and construct superior structures. Part I was reprinted in the March issue of *Oregon Geology*. Photos are by Don Dupras except as noted. —*Editor*

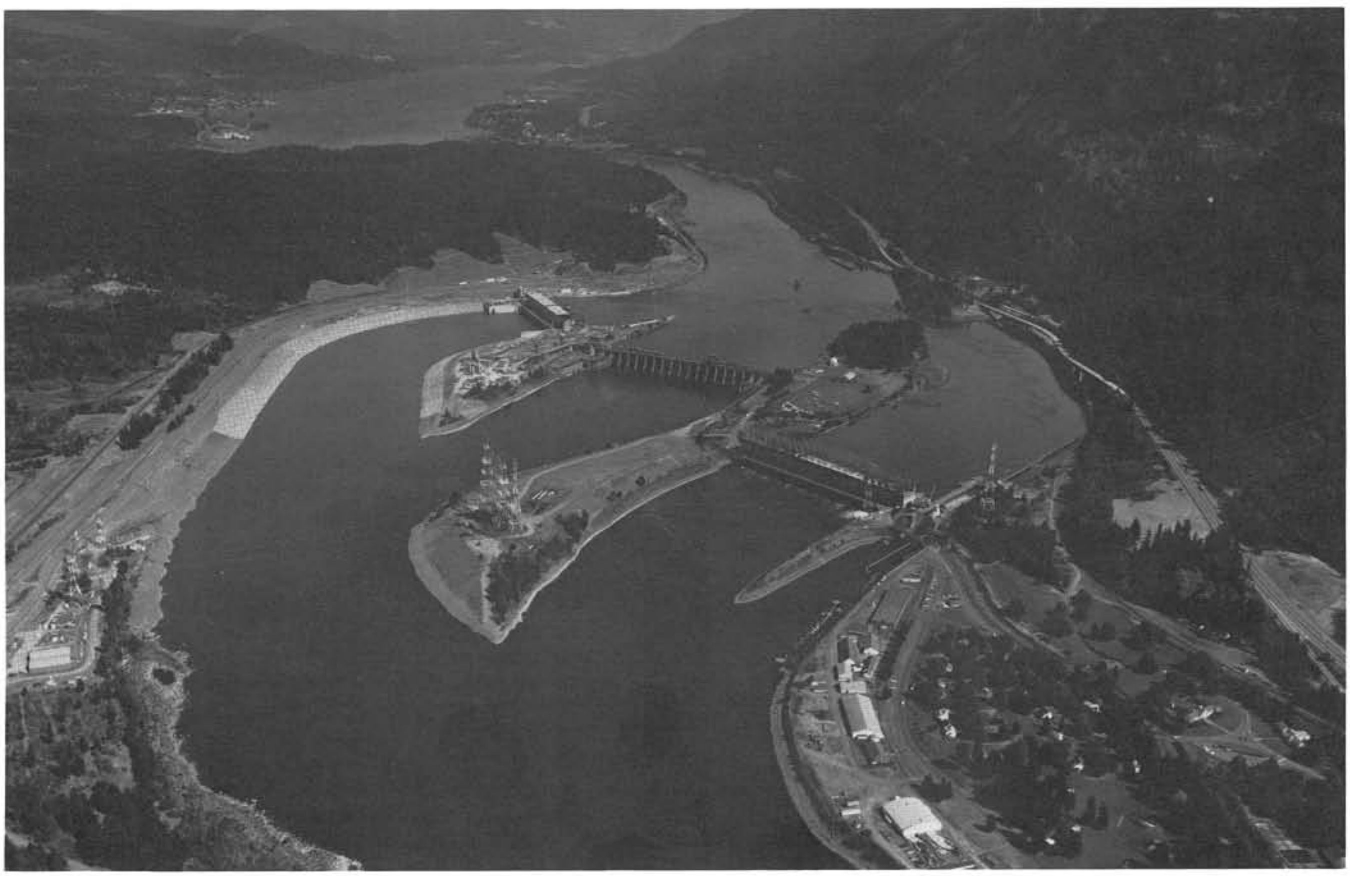
DEPENDENCE ON CONCRETE

Concrete is the least expensive, most plentiful, and most commonly used building material on earth. Annual world consumption of concrete is nearly one ton for every person on the planet. The raw materials for making concrete—cement, aggregate, and water—are abundant and are found in nearly every country. Concrete technology can either be adapted to labor-intensive methods frequently used in developing countries or to highly mechanized processes common in the United States and other industrialized countries (Weisburd, 1988).

Nearly all modern buildings stand on concrete foundations, and many are constructed with concrete frames, floors, walls, and roofs. Water is carried through concrete pipes, cars and trucks use concrete highways, planes land on concrete runways, and ships berth at concrete docks. It is hard to imagine our society without the benefit of concrete.

Concrete consumption increases as the population grows, and there is a corresponding demand for housing, manufactured goods, and related services. World concrete manufacture has risen steeply in the past decade; the rate of concrete consumption is expected to increase as developing nations continue to expand their infrastructures. Massive concrete projects, such as hydroelectric dams, airports, and aqueducts, are being constructed throughout the world, and many more are planned.

Annual use of concrete in the United States amounts to twice the total of all other construction materials combined—such as wood, structural steel, brick, tile, aluminum, and building glass. At a cost of about two cents a pound, the value of all concrete-based structures in the United States is estimated to be $6 trillion (Weisburd, 1988).



Bonneville Lock and Dam on the Columbia River, approximately 30 mi east of Portland, Oregon, connecting the Oregon and Washington sides of the river over a distance of about three-quarters of a mile. Built originally between 1933 and 1937 and enlarged in the early 1970's, the dam now combines the oldest and newest federal power plants on the Columbia. Lake Bonneville, the 48-mi-long reservoir impounded by the dam, is the first in a series of navigable lakes that are part of a water highway running 470 mi from the Pacific Ocean to Lewiston, Idaho. The Bonneville Lock and Dam project was placed on the National Register of Historic Places in 1986 and has been designated as a National Historic Landmark. Enormous quantities of concrete were used in this mass-concrete construction. Photo courtesy of U.S. Army Corps of Engineers, Portland District.

In addition to producing more portland cement than any other state, California also produces more concrete aggregate than any other state. In 1987, California produced an estimated 135.7 million tons of construction aggregate worth about $536 million (Burnett, 1988).[1] Of the ten largest aggregate producers in the United States, eight are in California (Table 1) (Rukavina, 1988). Much of the aggregate is used in concrete.

Table 1. *Ten largest aggregate plants in the United States (from Rukavina, 1988)*

Rank	Company (plant name)	County, state	1987 production in millions of tons
1	Koppers/Sully-Miller Company (Irwindale 67)	Los Angeles, CA	4.62
2	CalMat Company (Sun Valley)	Los Angeles, CA	4.60
3	Koppers/Kaiser Sand and Gravel Company (Radum)	Los Angeles, CA	3.90
4	A. Teichert and Son Sand and Gravel (Perkins)	Sacramento, CA	—*
5	Lone Star/Northwest Aggregates Company (Steilacoom)	Pierce, WA	3.51
6	Transit Mix Concrete Company (Azusa)	Los Angeles, CA	3.50
7	Livingston-Graham Company (Irwindale)	Los Angeles, CA	3.46
8	Owl Rock (Azusa Spreading Grounds)	Los Angeles, CA	3.20
9	Salt River Sand and Rock (Dobson)	Maricopa, AZ	—*
10	Jamieson Company (Pleasanton Pit)	Alameda, CA	2.30

* Production figures are proprietary.

CONCRETE INTEGRITY

When made in the appropriate way, concrete is durable and permanent. Some concrete structures have retained their integrity for over a century. However, if improper methods or inferior ingredients are used, concrete can be easily rendered worthless. Even after it is poured, concrete can be damaged by attack from acids and sulfates. Sulfates, such as sodium sulfate (Na_2SO_4), are especially harmful because they form sulfuric acid, which attacks the lime compounds in concrete. Contact with these deleterious compounds has to be avoided when using normal concrete.

For some construction jobs, engineers use special cements and techniques to design concrete structures that are better able to resist attack from injurious chemicals. For example, in areas where concrete will be exposed to severe sulfate attack, such as from sulfate soils or ground water, sulfate-resistant cement concrete is used.

Spillway of Bonneville Dam (photo above). The term "mass concrete" used for this kind of construction refers to the fact that the concrete in these structures often is several feet thick. Photo courtesy of Bonneville Power Administration.

Harvey O. Banks delta pumping plant, southern area of the Sacramento-San Joaquin delta, California, is shown in the distance. This plant marks the beginning of the California Aqueduct, the largest aqueduct system in the world. Over 8 million yd³ of unreinforced concrete was used, and much of the aqueduct is 64 ft wide at the top, 32 ft deep, and 40 ft wide at the base. The average thickness of concrete is about 4 in. Photo courtesy of the California Department of Water Resources.

Inept handling procedures can also be harmful to concrete. Storing a sack of ready-mixed concrete in a damp garage for several years can make it nearly useless, because the cement grains will absorb water, the concrete will take much longer to harden, and it will have reduced strength.

Aggregate

Poor-quality aggregate can also damage concrete structures. Because about 75 percent of concrete by volume is aggregate, it is critical that clean, hard, and durable sand and gravel be used. Excessive amounts of silt, clay, coal, lignite, and sulfide minerals (such as pyrite, FeS_2; cinnabar, HgS; and pyrrhotite, FeS) in aggregate may stain or seriously weaken the concrete (Kosmatka and Panarese, 1988).

It is also important that aggregate be nonreactive with the cement. Because of its chemistry, portland cement produces a highly caustic solution when mixed with water to make concrete.[2] Nearly all gravels react to some extent with this caustic solution. The reactive alkali content of concrete is commonly denoted by the sodium oxide (Na_2O) content in the portland cement. On a limited basis, this alkali reaction increases the strength of concrete. However, when the alkali reaction is excessive, the concrete will seriously expand, crack, and lose its integrity.

Aggregates that contain excessive amounts of certain silica minerals will react with the alkali in the cement and damage the concrete. Opal, chert, chalcedony, and other cryptocrystalline quartz minerals as well as some rhyolites and certain other volcanic rocks that contain abundant microfine hydrous silica will adversely react with portland ce-

[1]By comparison, Oregon's production of construction aggregate in 1988 totaled an estimated 13.6 million tons, worth about $44 million (U.S. Bureau of Mines preliminary survey).

[2]Because of the caustic chemistry of wet cement, it is desirable to avoid prolonged contact between fresh concrete and skin surfaces. Skin areas that have been exposed to wet concrete should be thoroughly washed with water.

ment, swell in size, and eventually crack the concrete (Legget and Karrow, 1983). If it is necessary to use reactive aggregates for practical reasons, engineers can design sound concrete structures using more expensive sulfate-resistant cement (also called "low-alkali cement").

ADMIXTURES

Engineers often custom-design specific jobs by including chemical compounds called "admixtures" within concrete. In addition to the commonly used admixtures that accelerate or retard the curing of concrete, many other admixtures can be used in concrete mixes for specific tasks. Admixtures strengthen concrete and make it more resistant to heat and chemical attack and less susceptible to shrinkage and cracking. Researchers in laboratories throughout the world are experimenting with admixtures that will be used to build superior concrete structures. Two commonly used types of admixtures are air-entraining agents and workability agents.

Hood River Bridge, Hood River, Oregon. Reversing 10° curves were used in this project to connect roads running on opposite sides of Hood River. Approximately 3,000 yd³ of concrete were used, cast in place and post-tensioned. Photo courtesy of the Oregon Concrete and Aggregate Producers Association (OCAPA).

Air-entraining agents

Up to three percent of the volume of standard concrete mixes contain air voids or bubbles that become entrapped by normal mixing methods. In addition, concrete can be foamed with varying amounts of air to make air-entrained concrete. Such concrete has remarkable cost-saving thermal insulation properties and reduces the dead-load weight of concrete structures. However, the most important and most widely used characteristic of air-entraining agents is the resistance to freeze/thaw cycles they give concrete structures.

Water exerts nearly 2,000 pounds of pressure per square inch (psi) as it freezes and expands. Residual amounts of water within the concrete can cause extensive damage through repeated freezing and thawing. The air bubbles in air-entrained concrete give the water enough room to expand as it freezes and vastly improve the resistance of concrete to repeated freeze/thaw cycles. Air-entrained concrete is used to make roads, buildings, and airport runways in regions where icy conditions are common (Kosmatka and Panarese, 1988).

One common method of producing these minute air voids is to add aluminum powder to the concrete mix. The aluminum reacts with the lime and forms very small hydrogen bubbles. When thoroughly mixed, the cured concrete contains evenly distributed bubbles. Other methods of air-entraining concrete are to add synthetic detergents, various sulfonated compounds, and fatty acids (such as oleic acid, $C_{17}H_{33}COOH$) to the mixture. Each of these compounds reacts with specific ingredients in the concrete mix to produce bubbles.

Air-entrained concrete contains from 4 to 9 percent air voids by volume, and the air bubbles range in diameter from 0.003 to 0.05 in. One drawback of air entraining is that it reduces the compressive strength of concrete. However, the reduction in compressive strength is generally not more than 15 percent (Kosmatka and Panarese, 1988).

Aerated concrete is related to air-entrained concrete and is a recently developed specialty concrete. It is made by using powdered aluminum to react with cement, water, and additional lime. The mixture is then heated and pressurized with moisture in a large autoclave, causing the concrete to expand and harden within a few hours. The reaction between the powdered aluminum and the lime forms hydrogen gas. The resulting concrete is chemically inert, strong, and so lightweight it can float on water. Aerated concrete has a cellular internal structure and is primarily used for its high thermal-insulation properties. It is also called "gas" or "cellular" concrete (Encyclopedia Britannica, 1984).

Workability agents

The term "workability" refers to the ease with which freshly made concrete can be placed around reinforcing bars and cables and into tight areas of a form. One of the easiest and most widely used methods of increasing the workability of concrete is to add water; however, this practice lowers concrete strength and durability. Since Roman times, engineers have known that strong, durable concrete requires a low water-to-cement ratio, which makes it stiff and laboriously difficult to place and work. Only the amount of water actually needed for hydration will produce high-strength concrete that is watertight, abrasion-resistant, and durable. As any concrete worker knows, however, handworking a stiff concrete mix can make for a long day.

For the past 20 years, researchers have experimented with a group of admixtures, called "plasticizers," that can increase the workability of a concrete mix without lowering its strength. During the past decade, an improved group of workability admixtures called "superplasticizers" has been developed.

Superplasticizers are important because they significantly increase workability without adding water. They do not harm the concrete. By using superplasticizers to increase workability, the compressive strengths of normal concrete mixtures have more than doubled. Superplasticizers are a family of sulfated organic chemicals, such as sulfonated formaldehyde and lignosulfonic acid, that make concrete soupy.

Fair Oaks Bridge at Sutherlin, Douglas County, Oregon, a structure that has received a number of awards for its use of concrete. The reinforced-concrete arch bridge uses both precast and cast-in-place concrete. Precasting of the arch ribs and columns saved greatly on forming costs, while the site-cast, post-tensioned deck system allowed the flexibility needed to construct grades and cross-slopes to meet traffic safety requirements. Photo courtesy of OBEC Consulting Engineers, Eugene, Oregon.

Concrete state office building in Sacramento, California. The concrete walls are nearly 7 in. thick. The high mass enables the concrete to store and release large amounts of thermal energy. In other words, concrete is used to moderate temperature swings and save on heating and cooling costs. In the hot Sacramento summers, the interior walls absorb and store heat during the day and radiate it at night. The thick concrete walls and floors help maintain a steady interior temperature year-round.

Research scientists know that superplasticizers somehow change the surfaces of portland cement grains in the concrete, but they do not yet understand exactly how the change takes place. Once researchers fully understand how superplasticizers and other admixtures function, better methods and materials will be used to make concrete structures with vastly increased compressive strengths (Weisburd, 1988).

STRUCTURAL CONCRETE APPLICATIONS

Concrete is widely used as a building material primarily because it has tremendous compressive strength. Other important reasons include its versatility, availability, durability, and cost-effectiveness. Structural concrete is so universally used that engineering practices and standards for concrete design are much the same worldwide.

Three common types of concrete used in structures are (1) reinforced concrete, (2) prestressed concrete, and (3) precast concrete.

Concrete floor panel being placed by means of a tremie line. The concrete was made in a nearby batch plant, transported to the construction site by ready-mix trucks (seen at the base of the building), pneumatically pumped five stories high, and then placed into position by workers.

Reinforced concrete

The advent of reinforced concrete in the 1850's ranks as one of the greatest achievements in civil engineering. Because of its weak tensile strength, nearly all concrete used in construction is reinforced with steel bars, rods, and, more recently, synthetic and steel fibers. These reinforcing materials are bonded to the surrounding concrete so that stresses are transferred between the two materials.

Strength of concrete and its reinforcing materials determine the load-carrying capacity of concrete structures. Reinforcing materials are generally not needed for relatively simple concrete projects, such as concrete sidewalks or residential driveways. However, for large structures (buildings and bridges) that must sustain intense stresses, reinforced concrete is required.

Steel rebar is the most commonly used reinforcing material in concrete. Because concrete and steel undergo about the same amount of thermal expansion, they can be used together without fear of cracking and weakening the structure. Reinforced concrete structures require less maintenance than steel or wooden structures and are frequently less expensive to build. When large structures are needed in remote regions, architects and engineers generally prefer reinforced concrete over other materials because it is more practical.

It is important that rebar adheres firmly to the concrete. To increase the bind, rebar is ribbed and sometimes allowed to corrode in air, so that its steel surface will have a rough texture.

Marine concrete facilities, such as harbors, can be significantly damaged by corrosion from seawater. Chlorine in the seawater chemically attacks the steel rebar in the concrete, seriously weakening the structure. Since the 1970's, epoxy-coated rebar has been successfully used in marine facilities for protection against damage from corrosion. Epoxy-coated rebar reduces the corrosion rates by 41,000 percent and is impervious to moisture and chlorine ions.

Ten-story building in San Francisco, California. Prestressed concrete panels were used on the exterior cladding because of their low weight, uniformity, and sharp profiles. Advances in concrete continue to expand its versatility. Photo courtesy of the Prestressed Concrete Institute.

Construction of the San Diego, California, aqueduct in 1976. Each prestressed concrete-pipe section is 8 ft in diameter and weighs 40 tons. The aqueduct is being placed on a 55° slope near Fallbrook, California. Photo courtesy of Ameron.

Prestressed concrete

As useful as reinforced concrete is, under a heavy load, long-beam supports will bend downwards, as shown in diagram on right, section (A). Engineers have devised a resourceful solution to this serious drawback by intensely stretching high-strength steel cables before the concrete bonds to them. After the concrete is poured and allowed to harden, the force that produces the stretch in the steel cables is released, and the concrete becomes compressed, as shown in diagram sections (B) and (C).

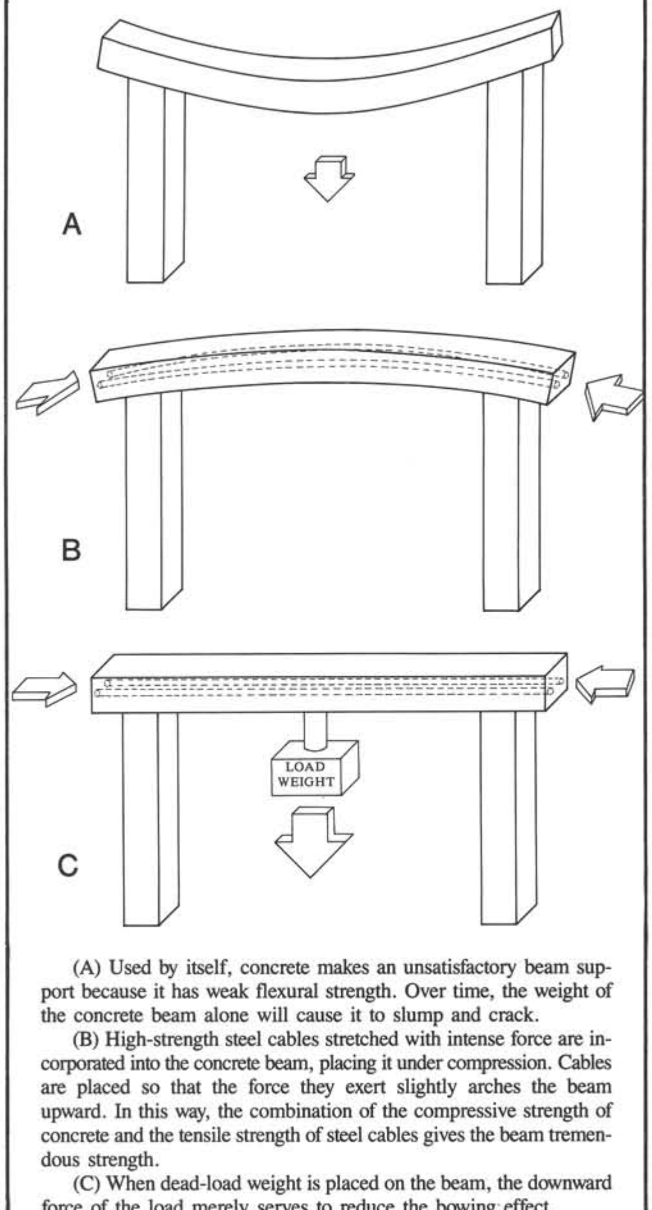
The primary reason for prestressing concrete is to give long-span beams great strength while at the same time lessening the thickness of the beam. Prestressed concrete beams are able to support very heavy loads and are engineered to precise specifications.

The force of the cables tends to warp the beam, similar to the way a bow is arched (diagram section B). When the beam is placed into position and load weight is applied, the downward force merely serves to reduce the bowing effect (diagram section C). As a result, the strength of the beam under load is immense. The stresses imposed on the reinforcing rods are engineered to be larger than any load weight applied to the beam. In diagram section (C), the load weight on the beam is placed beneath it for descriptive purposes. In practice, engineers use prestressed beams tailor-fitted to support load forces that act on the beam from any conceivable orientation (Waddell, 1976; McGraw-Hill Encyclopedia of Science and Technology, 1987).

Two general methods of stressing concrete are used: (1) pretensioning concrete and (2) post-tensioning concrete. High-quality steel cable is used in these stressing methods because of its great strength. In the pretensioning method, steel cables are placed under tension by stretching them with great force at both ends with hydraulic jacks.

PRESTRESSED CONCRETE

Concrete is strongest when it is compressed. Steel is strongest when it is stretched (placed in tension). These two parameters are combined in prestressed concrete.



(A) Used by itself, concrete makes an unsatisfactory beam support because it has weak flexural strength. Over time, the weight of the concrete beam alone will cause it to slump and crack.

(B) High-strength steel cables stretched with intense force are incorporated into the concrete beam, placing it under compression. Cables are placed so that the force they exert slightly arches the beam upward. In this way, the combination of the compressive strength of concrete and the tensile strength of steel cables gives the beam tremendous strength.

(C) When dead-load weight is placed on the beam, the downward force of the load merely serves to reduce the bowing effect.

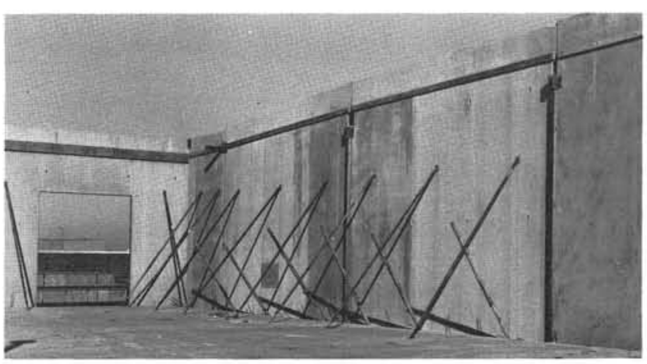
The concrete beam is poured (or "cast") around the cables in the normal way. When the concrete hardens, the tension placed on the cables by the hydraulic jacks is released. The prestressing force in the steel cables is transferred to the surrounding concrete, and the concrete is placed under compression.

In the post-tensioning method, a reinforced concrete beam is cast and hardened with holes or channels passing through it. After the concrete has completely set, steel cables called "tendons" are threaded through the channels, placed under extreme tension by hydraulic jacks, and anchored to the end of the beam or slab.

Structures that incorporate prestressed concrete are more costly than normal reinforced concrete structures because of the high-strength steel cables and increased labor costs. Steel cables used in prestressed

Carpenters making the forms for precasting panels for a tilt-up building. The 7-in. concrete panels will be cast on the completed concrete floor slab, then lifted (or tilted) by crane into a vertical position. Door frames are positioned before casting. Since World War II, the manufacture of tilt-up buildings has steadily increased because they are practical. The main advantage of tilt-up buildings is the elimination of vertical formwork for the walls.

Precast concrete panels for the tilt-up building with the forms removed. The rebar and bolts embedded in the concrete add strength.



The 22-ft-tall panels lifted into place and temporarily supported by 2-in. -thick steel rods embedded in the concrete. After the panels are bolted together and the base is cast and hardened, the rods will be removed.

The finished product. Tilt-up buildings are cost effective, long lasting, and relatively fast to construct.

concrete typically have minimum tensile strengths of 270,000 pounds per square inch for diameters of 0.25 in. Precise construction practices and close monitoring are required to manufacture prestressed concrete members and structures. Such structures can withstand very great forces and are frequently used in bridges, large storage tanks, tunnels, high-rise buildings, and dams (Waddell, 1976, 1985; McGraw-Hill Encyclopedia of Science and Technology, 1987).

Precast concrete

Second in tonnage to ready-mix concrete is the production of precast concrete. Concrete sewer pipes, blocks, wall panels, beams, trusses, and girders are first cast in a fabrication yard, allowed to harden, and then trucked to the building site. Nearly all prestressed concrete structures are precast. Very heavy concrete structures, such as concrete floor, roof, and wall panels, are commonly precast, allowed to harden at the building site, and then hoisted by cranes into position. Advantages of precasting concrete are that it (1) allows for better quality control; (2) enhances architectural design; and (3) is often more economical and efficient, because the casting can be done away from the construction site.

SPECIALTY CONCRETES

More than 50 kinds of specialty concretes made with portland cement are used in the United States. Specialty concretes have unusual properties that are used for specific purposes. Four common specialty concretes are (1) lightweight concrete, (2) heavyweight concrete, (3) fiber-reinforced concrete, and (4) high-strength concrete.

Lightweight concrete

Lightweight concrete is similar to normal-weight concrete except that it is made with aggregates that have low densities. It is primarily used to reduce the dead-load weight in concrete structures. Compared with the weight of normal concrete, which ranges from 130 to 155 pounds per cubic foot, lightweight concrete weighs from 85 to 115 pounds per cubic foot. A frequent use of lightweight concrete is in high-rise office floors. Pumice, scoria, vermiculite, perlite, and specially fired shales and clays are used in this type of concrete instead of the usual sand and gravel (Kosmatka and Panarese, 1988).

Heavyweight concrete

Concrete made with heavy materials, such as steel aggregate, is used for radiation shields in nuclear power plants. Heavyweight concrete normally weighs from 200 to 360 pounds per cubic foot. Goethite (specific gravity 3.4 to 3.7), barite (specific gravity 4.0 to 4.6), and limonite (specific gravity 3.4 to 4.0) are suitable for use in the lower weight ranges; hematite (specific gravity 4.9 to 5.3), magnetite (specific gravity 4.2 to 5.2), and ilmenite (specific gravity 4.3 to 4.8) for the medium-weight ranges; and steel punchings (specific gravity 6.2 to 7.8) are used in the upper-weight ranges (Kosmatka and Panarese, 1988).

Award-winning private residence in Salem, Oregon, built with precast, lightweight, cellular concrete made of sand, cement, and foam. The new material allows easy handling, sawing, even nailing with regular nails. It also is rot- and termite-proof, resistant to fire, and has good sound-proofing and insulating qualities. This home also won an Oregon State Award based on energy efficiency, cost, and marketability. Photo courtesy of OCAPA.

Powdered, lighter weight strontium and borate minerals, such as colemanite and borocalcite, are sometimes used in heavyweight concrete to aid in absorbing X-rays and gamma rays. The strength of heavyweight concrete is comparable with normal structural concrete.

Fiber-reinforced concrete

The corrosion problems encountered with steel rebar prompted the development of fiber-reinforced concrete. Fibers of steel, natural cellulose, glass, carbon, fiberglass, polypropylene, and bamboo are used. The fibers typically are round, flat, or crimped and range in length from 0.25 to 3 in. Content of fibers in concrete is typically 2 percent by volume but may range up to 14 percent when steel fibers are used (Kosmatka and Panarese, 1988).

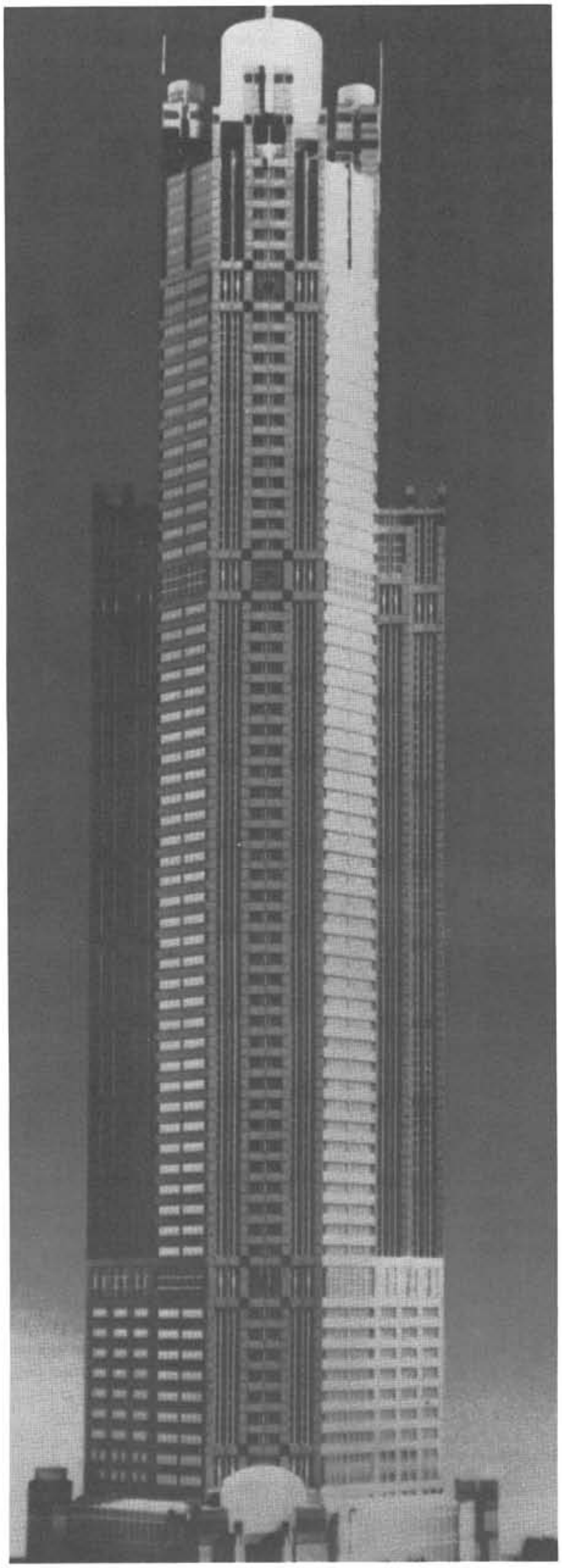
Advantages of the use of fiber-reinforced concrete are that it (1) reduces construction time by reducing the amount of rebar needed, (2) increases impact resistance, (3) lessens permeability, and (4) prevents microcracks that are common in concrete.

Fiber-reinforced concretes are effectively used in applications that do not require constant heavy stress, such as in airport runways and floors in skyscrapers. The increased structural support this specialty concrete provides in tight areas where reinforced rebar concrete cannot be placed is an added benefit.

High-strength concrete

Compared with normal concrete that has unconfined compressive strengths ranging from 2,500 psi to 5,000 psi, high-strength concrete is generally defined as having a compressive strength in excess of 6,000 psi. Superplasticizing admixtures are commonly added to high-strength concrete mixes to increase workability. Tough, durable aggregate is also needed. Just a few years ago, 10,000-psi concrete was considered noteworthy; today, engineers are using 19,000-psi concrete,

Airport control tower at Mahlon-Sweet Airport in Eugene, Oregon. Precast concrete is used in this construction, and the design can easily be repeated at other locations. Photo courtesy OCAPA.



Model of the Wacker Drive Building, Chicago, Illinois. When completed by the end of this year, at 946 ft high, it will be the tallest concrete building in the world. The size of this building is made possible by the use of high-strength concrete. Photo courtesy of Kohn, Peterson, and Fox.

and researchers predict that near-future concrete mixes will have compressive strengths over 30,000 psi (Godfrey, 1988). Mathematical models exist for 40,000-psi concrete.[3]

The use of high-strength concrete has increased in recent years. High-strength concrete costs more than conventional concrete, but less of it is needed. Combined with stronger lightweight aggregates, high-strength concrete reduces the dead-load weight in buildings and increases usable floorspace while reducing column and beam size. With the development of stronger and lighter concrete, engineers are using innovative designs to build taller concrete skyscrapers and stronger bridges, tunnels, dams, and other structures.

High-strength concrete is frequently used where large stresses are anticipated, as in skyscrapers. For example, the tallest concrete building in the world is currently being constructed in Chicago using high-strength concrete. Known as the Wacker Drive Building, much of the estimated 110,000 yd of concrete used in its construction will have compressive strengths of 12,000 psi. When the $110-million skyscraper is completed in 1989, it will have 50 floors and will be 946 ft high. Only ten steel-framed buildings will be taller than that in North America. Because it is cheaper, reinforced and prestressed concrete instead of the more traditional steel frame is being used to construct this skyscraper. Building costs will be reduced by several million dollars (ENR, 1988; Robison, 1988).

Another notable concrete building, the Two Union Square Building in Seattle, Washington, is being built using the highest strength concrete ever employed in a conventional building. Much of the 720-ft-high building will incorporate 19,000-psi concrete, nearly four times the strength of normal structural concrete. Superplasticizers and quartzose aggregate are used in the concrete mix (Godfrey, 1988).

Other applications of high-strength concrete include using 20,000-psi concrete in recently constructed bank vaults and prestressed beams. More than ten years ago, 15,000-psi concrete was used in missile silos. Higher strength concrete is currently being used to build similar military facilities.

TECHNOLOGY

A variety of new products is being developed, such as fibrous, polymer, and polymer-impregnated concretes. These new materials are lighter, stronger, more resistant to heat and chemical attack, and more impervious to fluids than traditional types of concrete.

Polymers and epoxies

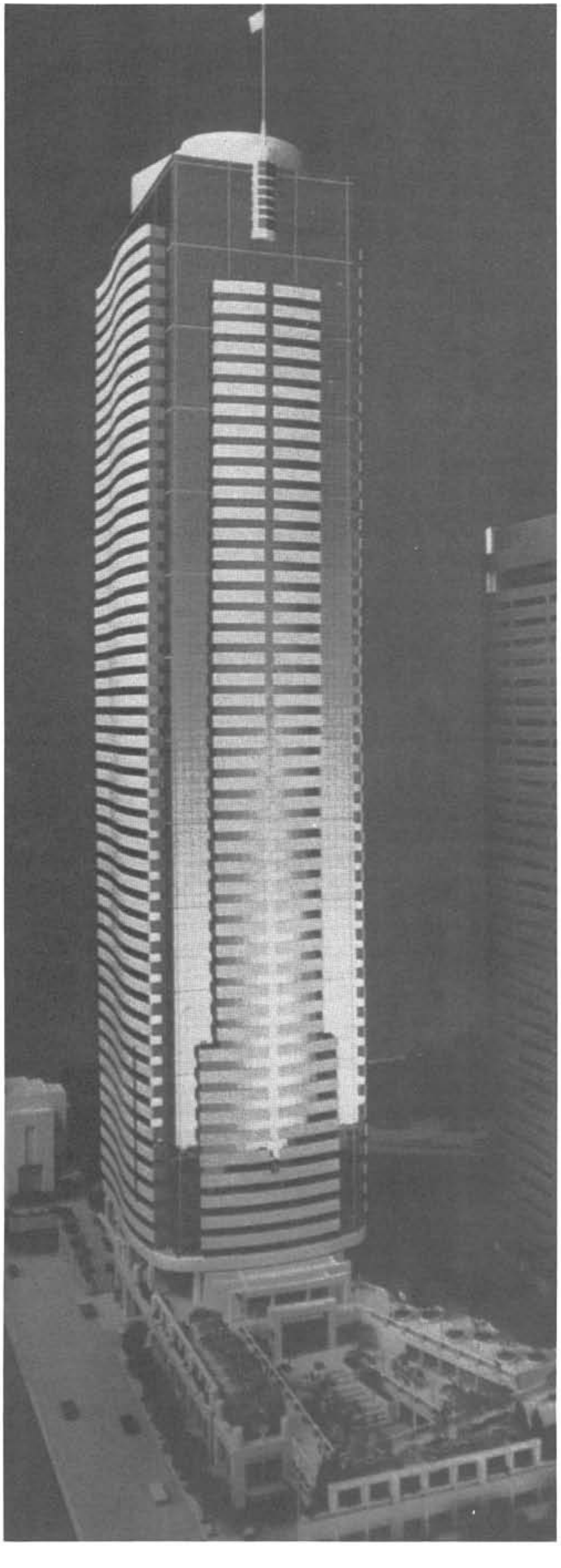
Synthetic polymers and epoxies are used in limited quantities primarily for repairing damaged concrete structures. Polymers are very large molecules that are composed of repeated motifs of smaller molecules. Examples of common polymers include plastics and synthetic fibers, such as rayon, orlon, polyethylene, and fiberglass. Epoxies are a class of thermoplastic polymers (they become soft when heated and hard when cooled). Epoxies, also called "epoxy resins," are chemically inert and strong adhesives. When polymers and epoxies are properly placed in damaged concrete, the repaired portions are often stronger than the surrounding concrete.

Polymer-impregnated concrete is made by heating the damaged concrete structure to remove any residual moisture. Heated polymer plastic is then forced under intense pressure into the air voids that ordinarily occur in concrete. In polymer concrete, monomer and polymer resins entirely replace the portland cement. Polymer-impregnated concrete and polymer concrete are used to a limited extent in patching and repairing concrete structures and for some road-pavement surfaces. Epoxy adhesives are primarily used to repair concrete structures and to strengthen precast concrete segments.

RESEARCH

In the future, architects and engineers will use new techniques and improved concretes that are currently being developed. Advanced con-

[3]For comparison, the compressive strength of granite is about 22,000 psi, and the compressive strength of basalt is about 25,000 psi.



Model of the 759-ft-high, 62-story Two Union Square Building currently under construction in Seattle, Washington. It is being built with the strongest concrete ever used in a conventional building. Some columns have been fashioned with 19,000-psi high-strength concrete. In 1947, construction concrete had a compressive strength of 3,500 psi. By 1960, 5,000-psi concrete was being used, and today 12,000-psi concrete is frequently used. Researchers predict that by the year 2000, 25,000-psi concrete will be available. Photo courtesy of Skiling Ward Magnuson and Barkshire.

crete-based materials have already begun to augment and replace more conventional building materials such as wood, tile, brick, and steel.

On the surface, portland cement concrete appears to be a simple material. Its internal structure, however, is very complex. In research laboratories, scientists are only now beginning to understand the complex chemical reactions that occur as common concrete hardens. Iridium and platinum crucibles are used to minimize contamination in the experimental concrete mixtures.

To better understand the internal structure of concrete and how it forms, researchers in Belgium and England conducted experiments using heavy water (deuterium oxide, D_2O) instead of normal water to make concrete. The heavy water permits neutron scattering analyses that yield information about the microstructure of the concrete. Because heavy water costs more than $4,000 per pint, this may have been the most expensive concrete ever made (Hansen, 1982).

CONCLUSION

Concrete has enhanced the quality of our lives and will continue to do so far into the future. Experts predict that concrete will become lighter and stronger, and its use in long-span bridges, high-rise buildings, highways, and myriad other applications will increase. The versatility and multifunctions of concrete have captured the imagination of architects, engineers, and research scientists. Architects will continue to design concrete structures with enhanced, eye-appealing colors and textures that promote the technical artistry of concrete. Engineers will find innovative uses for improved specialty concretes, and research scientists will develop superior concrete-based materials.

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A note on the origin of Bull Run and Lost Lakes, Western Cascades, Oregon

by David R. Sherrod and Leda Beth G. Pickthorn, U.S. Geological Survey, Menlo Park, CA 94025

We were pleased to read Allen's (1989) description of the evidence for glaciation in the Western Cascades subprovince of the Cascade Range near the Columbia River. We add a twist to the story of Bull Run Lake, which is in Portland's Bull Run Watershed, Mount Hood National Forest, and clarify the setting of Lost Lake, which is located about 3 km to the north.

Allen was correct in describing the basin of Bull Run Lake as a cirque in the U-shaped upper part of Bull Run canyon. However, the natural dam is not of glacial origin, as suggested by Allen. Instead, it formed when a landslide moved off the northeast canyon wall near Preacher's Peak (Figure 1). The resulting hummocky ground is underlain by jumbled and broken basalt. Wise (1969) thought that the irregular terrain and abundance of fresh lava indicated a Quaternary lava flow. In his interpretation, the flow had to be relatively young—latest Pleistocene or Holocene—to have escaped excavation by late Pleistocene glaciers. Although we have not dated the lava in the landslide or near Preacher's Peak, its age is probably about 2 Ma, on the basis of a K-Ar age of 2.54±0.80 Ma (Table 1) from stratigraphically similar basalt lava near Thimble Mountain, 8 km southwest of Bull Run Lake. The landslide must be latest Pleistocene or Holocene in age, because it is unglaciated.

According to Allen (1989), Lost Lake was dammed by lava from Lost Lake Butte, a small (1.2 km³) basaltic shield volcano (Wise, 1969). We agree that Lost Lake's basin results from the fortuitous position of surrounding ridges and Lost Lake Butte, but the basin is closed, and the lake is impounded by ground moraines that fill a broad marshy area at its north end and choke a shallow drainage divide at the southeast end.

As an aside, Lost Lake Butte is older than latest Pleistocene glaciation, as indicated by two small cirques northeast of its summit. The morphology of the shield is characteristic of volcanoes younger than about 250,000 yr B.P.; older Cascade Range volcanoes are generally deeply gutted by glaciation. Lost Lake Butte may be much younger than 250,000 yr B.P., but presently there are no absolute ages with which to calibrate the progressive stages of erosion in young basalt or basaltic andesite shield volcanoes of the Cascade Range.

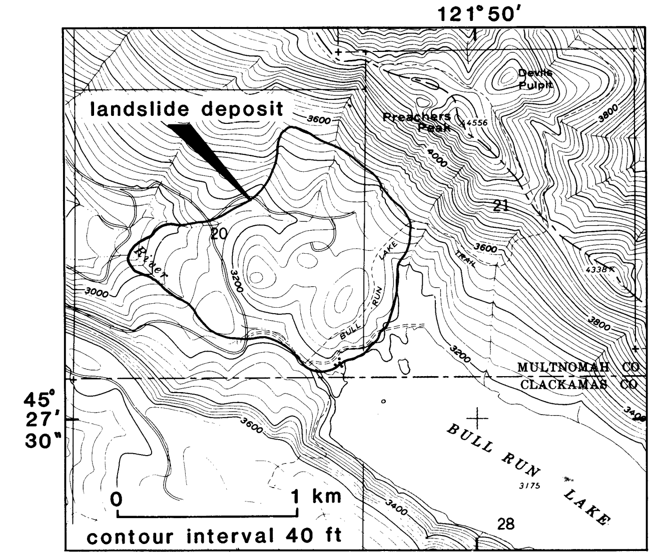

Figure 1. Map showing landslide deposit at mouth of Bull Run Lake. Base from U.S. Geological Survey, 1962.

Table 1. *Whole-rock K-Ar age of basalt from Thimble Mountain, 43°9.5' N., 122°4.0' W., Hickman Butte 7½-minute Quadrangle, Oregon.*

Sample number[1]	K_2O (wt %)[2]	$^{40}Ar_{rad}$ (10^{-11} moles/g)	Percent $^{40}Ar_{rad}$	Calculated age (Ma)[3]	Assigned age (Ma)[4]
S5-47	(1.619)				2.54±0.80
	1.612	0.5998	41.0	2.57	
	1.608	0.5860	46.6	2.51	
	1.633				
	1.624				

Notes:

[1]Sample preparation and analytical work were done at U.S. Geological Survey by LedaBeth G. Pickthorn.

[2]Value in parentheses is arithmetic mean used in age calculation.

[3]K-Ar ages were calculated using the constants for the radioactive decay and abundance of ^{40}K recommended by the International Union of Geological Sciences Subcommission on Geochronology (Steiger and Jager, 1977). These constants are:

$$\lambda_\varepsilon = 0.580 \times 10^{-10} yr^{-1},\ \lambda_\beta = 4.962 \times 10^{-10} yr^{-1}, \text{ and } ^{40}K/K_{total} = 1.167 \times 10^{-4} \text{ mol/mol}$$

[4]Weighted mean of age from two extractions.

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Geophysical exploration: The first step in the search for new petroleum supplies

by Charles F. Darden, President, International Association of Geophysical Contractors, P.O. Box 460209, Houston, Texas 77056-0209

This is one of a series of articles on the oil and gas industry that have been written for *Oregon Geology* by people who work in various occupations within the industry itself. This particular article describes some of the geophysical techniques used in the exploration for and development of oil and gas resources. Earlier articles in this series included discussions of how oil and gas form and how wells are logged after they have been drilled. Future articles on the oil and gas industry will appear at irregular intervals in upcoming issues of *Oregon Geology.* —*Editor*

INTRODUCTION

With the cost of drilling an exploratory well in search of crude oil and natural gas supplies exceeding a million dollars in nearly all cases, geophysical exploration (primarily the seismic method) continues to increase in importance because it substantially improves the success rate of this effort. Additionally, seismic surveys are increasingly being used to help maximize production in known petroleum reservoirs.

Exploration geophysicists gather and analyze seismic, gravitational, magnetic, and other data to learn what minerals are in the earth and what are the shape and properties of subsurface rocks. From these data, they trace the sequence of rock layers and decide on the likelihood of finding oil in a particular onshore or offshore location. Derived from physics, one of the oldest branches of science, geophysics has become an integral part of the worldwide effort to find new petroleum supplies.

More than 40,000 professionals and technicians are employed in the United States alone as part of the geophysical exploration "team." Worldwide expenditures for the acquisition, processing, and interpretation of geophysical data as part of this process totaled $1.5 billion in 1987. While this highly complex business, which performs the first step in the petroleum exploration effort, often has very limited visibility, it is in fact a major industry in itself. For most people who encounter the industry, the only component they usually see is the seismograph field crew working in their localized area.

GEOPHYSICAL TOOLS

The seismograph provides the only direct way of acquiring subsurface structural information without drilling wells, and its success in supplying this information continues to increase through ever-evolving technological advances. Soundlike waves called "seismic acoustic waves" generated at or near the surface penetrate the earth's crust and reflect from subsurface rock levels back to the surface. There the reflected signals can be recorded, just as is done with radar. The geophysicist receives a printed record, called a "seismogram," from which he or she can measure the depth of various strata. When a series of seismic shots is made over a considerable distance, the resulting succession of seismograms shows a cross-section of the subsurface. Ideally, such a section reveals patterns of the strata below, such as faults, anticlines, folds, and other subsurface structures that might be oil- or gas-bearing.

In the industry's early days, dynamite was used almost exclusively for generating seismic waves, but today, mechanical sources of wave energy such as earth vibrators are also used. In one widely used vibratory technique called "shaking" rather than "shooting," a unit mounted on a truck or boat creates seismic waves by means of a vibrator pad that is lowered to the earth (or water when used offshore). In contrast to the ruggedness of the instruments used to create seismic energy, the seismometers used to "hear" seismic reflections (known as "geophones" when used on land and "hydrophones" when used at sea) are extremely sensitive instruments—so sensitive, in fact, that they are capable of detecting a strong coastal wind or a person walking on the surface a quarter of a mile away. Seismometers (commonly called "jugs" in industry jargon) are usually strung out in long lines, connected by electrical cables extending over the exactly surveyed seismic line, and placed directly on the ground. A similar process that will be discussed later takes place for marine operations.

Each seismometer picks up the signals bouncing off many layers of the subsurface and produces its own seismic "trace," which is recorded both on sensitized paper and on magnetic tape. The amount of time it takes for a seismic wave to bounce back from the various strata gives the geophysicist a clue to the depth of each rock layer. Improvements in digital recording instruments have vastly improved the geophysical industry's ability to record and play back seismic data collected. New computing methods and electronic equipment used to play back seismic recordings continue to overcome many of the noise and geophysical interpretation problems to make seismic exploration more valuable. Also, computerized display equipment now makes it possible to compress wide areas of seismic exploration into desk-size sections that can be more easily analyzed.

For many years, geophysicists have collected data along linear cross-sections of the earth. These surveys provided information beneath the survey line, which was usually displayed as a two-dimensional "slice" of the subsurface. Recently, seismometers have been distributed over a wider area on the earth's surface, and information has been collected throughout a volume of the subsurface. This acquisition method is called "three-dimensional" or "3-D" shooting. It provides a tremendous amount of information that can be analyzed only by powerful computers. Its use now enables drilling locations to be determined with greater confidence. Three-dimensional shooting is used not only as an exploration tool but also in exploitation or production work.

OTHER GEOPHYSICAL TOOLS

In addition to the seismograph, other tools are widely used by geophysicists to measure the various characteristics of the earth as part of the petroleum-finding effort. Of these, the best known are the magnetometer and the gravimeter. However, it should be noted that about 95 percent of the dollars spent on exploration geophysics involves the seismic method.

The magnetometer is an instrument that measures variations in the earth's magnetic field caused by changes in the magnetic properties of subsurface rocks. Resembling a large camera, the magnetometer is used both on the ground and in the air to accurately measure magnetic intensity. Each of the earth's three major classes of rocks—sedimentary, igneous, and metamorphic—have different magnetic properties according to their iron content. Sedimentary rocks associated with oil and gas generally have lower magnetic properties than other rocks.

The gravimeter, on the other hand, literally weighs the earth. It can detect variations in the gravitational pull of rocks that lie as much as several miles below the earth's surface. Because large masses of dense rock increase the pull of gravity, gravimeter readings at them with agreements made in new areas. Sometimes the permit agent travels hundreds of miles a day and may be days or weeks ahead of the actual seismic operation.

Surveying the route

Next comes the survey crew, which marks the exact route the seismic line will take. The survey crew also measures surface elevations along the line and specifies the points where sound waves will be generated and listening devices placed.

Laying out geophones and recording equipment

Following the surveyors, another part of the instrument crew pays out sensitive listening devices along the seismic line. These geophones pick up the reflected sound waves after they have been weakened by passing through miles of underground rocks. The geophone converts these signals into electric impluses that are transmitted by cable to the recording truck. Inside the truck are delicate electronic instruments that amplify and record the electric impulses for later computer analysis. Geophones and recording instruments are so sensitive that they can pick up footsteps scores of feet away.

Generating energy waves and recording data

Seismic waves may be generated several waves into the ground. Commonly used methods include surface detonations, shot-hole detonations, vibroseis, and air guns. Special equipment used and procedures followed for these four methods are discussed later in this paper.

Cleaning up the site

While seismic crews move rapidly from area to area, they exercise care to clean up along the seismic line so the area is left as near to its original condition as possible. The permit agent or another representative of the crew coordinates this effort to make sure that all the terms of the permit have been satisfied.

VARIED LAND SEISMIC ENERGY SOURCES

Illustrated below are the four most common methods for generating sound waves for land seismic exploration: surface detonations, traditional shot-hole operations, the vibrating energy source, and the air gun. Factors that influence the selection of a particular method include prior experience, environmental concerns, and economics. Whenever possible, exploration companies prefer to have flexibility in selecting the best method to be sure they obtain the highest quality geophysical data.

Surface detonations

Often specified by government permitting agencies in remote areas away from people is the "surface shooting" method. This is usually a portable operation, with helicopters used to transport workers and equipment along the survey line, avoiding the use of motorized vehicles and ensuring minimum impact on the land.

Explosive charges for surface detonation are mounted on wooden stakes above the ground.

Small charges are mounted on wooden stakes several feet above the ground in a pattern that could include from one to a dozen charges at each shot point. The detonation of these surface charges can be heard for a considerable distance, depending on such factors as surface terrain and weather conditions. However, the sound level is relatively low, and incidences of actual physical damage or serious disturbance of wildlife are extremely rare.

Traditional shot-hole operations

In this method, a hole is drilled, and an explosive charge is buried. Detonation of the buried charge creates a seismic sound wave. The typical seismic shot hole ranges from 10 to 200 ft in depth and is about 4 in. in diameter. Detonations are usually contained within the hole to force the energy generated downward through various rock strata, and the only sound that can be heard above the ground is a dull thud.

A shot hole is drilled, and an explosive charge is buried and later detonated to create a seismic sound charge.

Vibrating energy source

The vibroseis method involves surface vibration rather than detonations. A specially designed vibrator pad, mounted below a vehicle, is compressed against the ground and vibrated at regular intervals to create sound waves. Damage to the ground by vibrator pad is minimal. Several of these vehicles operate together to form the energy source. Difficult terrain often limits the use of this particular seismic energy source.

Specially designed vibrator pads located beneath the trucks are vibrated to create sound waves for the vibrating energy source method of exploration.

Air-gun operations

An air gun is a truck or tractor-mounted seismic source that uses compressed air. The air gun is contained inside a bag filled with water and discharges compressed air, which generates the seismic sound waves. The air-gun bag is mounted on the back of a truck. Damage to the ground by the bag is minimal. Up to four air-gun trucks may operate together for most seismic exploration work. This source is also limited by terrain and data-quality considerations.

An air gun using compressed air inside a bag filled with water is mounted on this truck and discharged to generate seismic sound waves.

OFFSHORE GEOPHYSICAL SURVEYS

Geophysical exploration activity also has been extensively adapted to the offshore environment. Modern seismic vessels are designed specifically for surveying, as is the equipment to interpret and refine the data received. But, instead of using the same equipment that is used onshore, such as "surface shaking" machines and geophones, seismic crews offshore generally use chambers, or air guns, containing compressed gases or fluids to generate the acoustic signals and hydrophones to pick up the returning sounds.

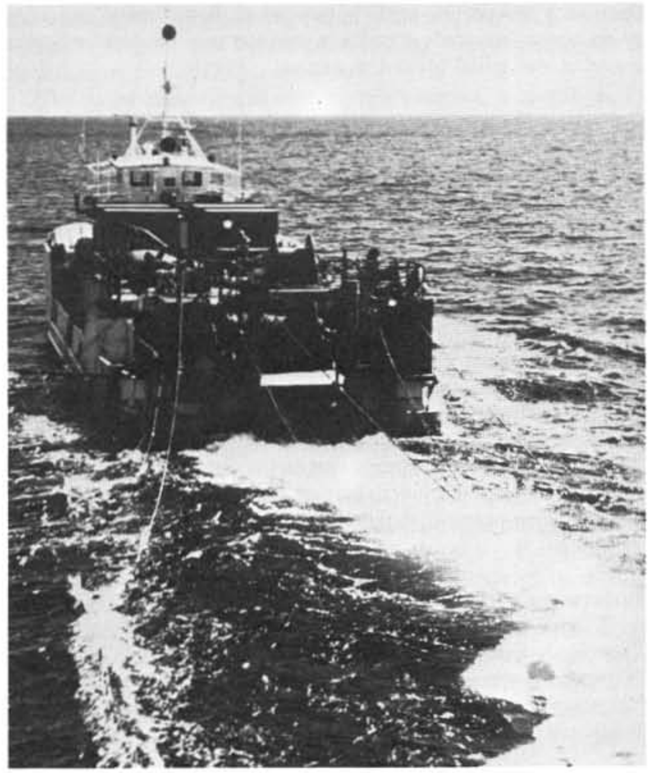
These confined "explosions" leave only air bubbles and a muffled thumping sound to attest to their presence and use. The chambers are trailed behind the vessel as it moves along a predetermined survey line. The crews activate the chambers at set intervals from onboard controls connected by cables to the energy source. Other cables contain arrays of hydrophones that receive the sounds created by the explosions as they echo off the underlying strata beneath the sea and transmit that information to the inboard seismograph and computers.

Prior to and throughout the survey, great care is taken to alert fishing or other vessels in the area to the presence of the survey vessel and its course. Sophisticated collision avoidance equipment is standard aboard modern seismic vessels. The vessels are kept on course through use of radar, loran, and satellite navigational equipment.

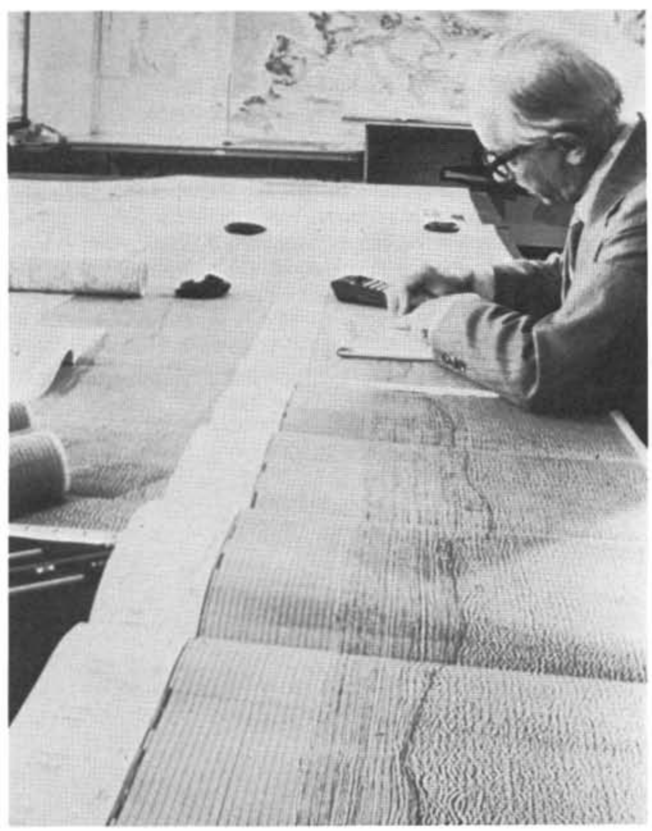
Other instruments keep track of the cable containing the hydrophone—the "streamer" —which may extend for nearly 2 mi behind the vessel. In sensitive fishing areas, marine biologists may accompany the seismic crews to monitor operations.

IMPORTANCE OF SELECTION OF SEISMIC ENERGY SOURCE

In both land and marine geophysical operations, subtle differences exist in both data-acquisition and data-processing techniques used by different companies. Individual companies select what they con-



Marine geophysical vessel towing (1) air guns that release compressed air to generate pressure impulses, and (2) hydrophones that receive the reflected signal generated by the air guns.



Geophysicist interpreting a seismic section composed of offshore reflection data.

sider to be the best seismic energy source that yields the highest quality data and is compatible with environmental and other goals. These differences in techniques of exploration companies contribute to the industry's overall success in locating new drilling prospects that otherwise would have been missed if only one survey had been conducted in the area and perhaps the wrong energy source was employed the first time.

When industry first has exploration interest in a particular region, a broad reconnaissance is done, and then the grid of survey lines is steadily tightened to target places where the data suggest favorable conditions exist. This goes from lines as far apart as 50 mi to as close as half a mile or less. Each time data are collected, the industry learns more about an area.

TRENDS IN GEOPHYSICAL EXPLORATION

In the United States, land acquisition for oil and gas exploration and development has declined over the last few years, and the main interest has moved offshore, in most cases to the Gulf of Mexico. Furthermore, exploration efforts are shifting more and more from the United States to other parts of the world, primarily the North Sea and the Far East, followed by West Africa.

Geophysical work in the oil industry is also changing, from exploration for new fields to development of existing fields. Five years ago, 90 percent of geophysical work in the oil and gas industry was in exploration. Today, more than half of the activity is funded from oil and gas companies' production budgets. □

Field trip guides for IGC offered

More than 7,500 geoscientists from at least 100 countries will meet in Washington, D.C., this summer, July 9-19, at the 28th International Geologic Congress (IGC). This is the first time in more than 50 years that this important gathering has been held in the United States. The IGC has met about every four years since the 1800's.

The written record of the Congress will consist of field trip guidebooks, short-course books, and abstracts. Field trip guidebooks and short-course books are now being offered for sale by the American Geophysical Union (AGU).

The field trip guidebooks cover distinct geographic regions and are written for the nonspecialist who has a geologic background. They contain road logs, describe geologic features, provide historical information, discuss the geologic processes operating in the region, and are illustrated with drawings, photos, and geologic maps. A total of approximately 130 field trip guidebooks will be available, ranging in length from 4 to 216 pages and in price from $6 to $35. Specially priced compilations are also offered. For IGC field trip participants, the cost of guidebooks is included in the trip fee. With one exception (Antarctica), the guidebooks will be released for sale after June 30.

Included among the field trip guidebooks for the western United States are the following:

- Snake River Plain-Yellowstone volcanic province (T305);
- Cascade Range (T306)
- Accreted terranes of the North Cascade Range, Washington (T307)
- Geologic evolution of the northernmost Coast Ranges and western Klamath Mountains, California (T308)
- Glacial Lake Missoula and the Channeled Scablands (T310)
- South Cascades arc volcanism, California and southern Oregon (T312)
- Cenozoic volcanism in the Cascade Range and Columbia Plateau, southern Washington and northernmost Oregon (T106)

Short-course books contain material from special classes that will be given during the IGC. The courses will cover such subjects as past and future climate, volcanic hazards, modeling ground-water flow, sedimentary-basin analysis, hydrothermal systems, and paleoenvironment.

For information about the IGC, contact Bruce B. Hanshaw, Box 1001, Herndon, VA 22070-1001; phone (703) 648-6053.

More information on the AGU publications is available from Alan Tourtlotte, AGU (address and phone below).

For book orders, contact AGU—Orders, 2000 Florida Avenue, NW, Washington, D.C. 20009. Call 1-800-424-2488 toll free or (in D.C. or outside the U.S.) AGU at (202) 462-6900. Electronic mail: Cust.Service/Edunet/Kosmos. Fax: (202) 328-0566.

—From AGU news release

Reports on five Gorda Ridge studies released

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released five reports presenting results of research on the Gorda Ridge, a sea-floor spreading region off the coast of southern Oregon and northern California. The reports, published as DOGAMI open-file reports, add more information to the ongoing research into the extent, nature, and effects of the hydrothermal venting that occurs along the mid-ocean ridge.

The studies were connected with two diving expeditions conducted in 1988—of the submersible *Alvin* in June and of the submersible *Sea Cliff* in September. They were part of a research program that was directed by the joint federal-state Gorda Ridge Technical Task Force, funded by the U.S. Minerals Management Service, and managed by DOGAMI. A particularly significant result of the *Sea Cliff* dives was the discovery, at the northern end of the ridge, of an active hydrothermal vent field, named the Sea Cliff Hydrothermal Field.

Sea Cliff diving and sediment studies on the Gorda Ridge, by R. Karlin, Mackay School of Mines, University of Nevada-Reno. A study concentrating on the possible relations between hydrothermal activity and metamorphism of the hosting sediments. Open-File Report O-89-04, 17 p., $5.

Soft-sediment hydrothermal vent communities of Escanaba Trough: Comparison with other vent and non-vent communities from similar depths in the deep sea and the influence of chemosynthetic production on the surrounding deep-sea benthic community, by J.F. Grassle and C.L. Van Dover, Woods Hole Oceanographic Institution. Description and discussion of biological and chemical data obtained during dives of both submersibles. Open-File Report O-89-05, 25 p., $5.

Biological results from DSV Sea Cliff exploration of the northern Gorda Ridge, by G.L. Taghon, College of Oceanography, Oregon State University. Description of biological communities of the Sea Cliff Hydrothermal Field. Open-File Report O-89-06, 4 p., $4.

Studies of hydrothermal effluents on the Gorda Ridge, by R.W. Collier, College of Oceanography, Oregon State University. Analyses of data from earlier dives, used in this report to develop the location of survey sites and dive targets as well as sampling equipment and strategies for the *Sea Cliff* dives. Open-File Report O-89-07, 13 p., $5.

Submersible observations and bottom-sample analyses of the Sea Cliff Hydrothermal Field, Gorda Ridge, by J.S. McClain and P. Schiffman, Department of Geology, University of California at Davis. Geologic study indicating the importance of the rift valley wall faults for hydrothermal circulation. The authors emphasize that future exploration for minerals should include work on the walls as well as the center of the rift valley. Open-File Report O-89-08, 27 p., $5.

All five reports are now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, Oregon 97201-5528. Orders under $50 require prepayment. □

DOGAMI honors mining operators

Bay View Transit operation at Squaw Creek near Seaside, Oregon, honored with the Outstanding Operator Award.

Central Oregon Pumice reclaimed mining area near Bend, Oregon, honored with the Reclamation Project Award.

On March 23, 1989, the Oregon Department of Geology and Mineral Industries (DOGAMI) presented its Outstanding Operator Award to Bayview Transit Mix, Inc., of Seaside and its Reclamation Project Award to Central Oregon Pumice Company of Bend.

Honorable mention for the awards went to Bracelin-Yeager Excavating and Trucking, Inc., of Coos Bay; Ohbayashi Corporation of San Francisco; Beaver State Sand and Gravel, Inc., of Roseburg; and Bend Aggregate and Paving Company of Tumalo.

The Operator Award recognizes operational design and conduct that lead to exceptional environmental protection. The Reclamation Award honors reclamation projects that exemplify the goals of the reclamation statutes of the state.

The award winners were chosen by a selection committee composed of representatives from the mining industry, the legislature, and environmental interest groups. DOGAMI's Mined Land Reclamation Program staff assisted in coordinating the award program.

The Outstanding Operator Award to Bayview Transit Mix, Inc., honored the company's initial development of a hard-rock quarry operation in Clatsop County near the Seaside-Cannon Beach highway interchange, on property owned by Cavenham Forest Industries.

Previous use of this property had been for timber production. A small hillside excavation had served the landowner's need of rock for log-hauling roads. The newly developed quarry, which ultimately will encompass 20 acres, is removed from public view by a private access road several miles long.

Bayview Transit settling pond with overflow system used to irrigate hillside vegetation.

After Clatsop County granted zoning approval, the operator received the permit for a commercial quarry site and began site development in August 1988. The soil removed from the natural 1:1 slope was deposited at the toe of the excavation face in what is known as a "compacted fill" (deposition by layers, each layer compacted by rollers before the next layer is started). The compacted fill was covered with crushed rock, its surface was sloped for drainage, and the area was developed as site for a crusher plant and stockpile.

Immediately downslope from the plant site, a sedimentation pond was excavated. A berm around the plant site will now direct surface-water runoff into the sedimentation pond. From the pond, the overflow will feed a trickle-irrigation system spread across the hillside, which is covered with a 10-year-old stand of Douglas fir and hemlock. Thus, the waste-water discharge is effectively separated from a Class I perennial stream nearby.

In October 1988, all slopes, banks, and other areas where bare soil was exposed were seeded with a mixture of several grasses and clover, and an organic mulch tackifier was applied.

Central Oregon Pumice was honored for its reclamation of mining claims identified as Devil's Flat 1 and 3. The 24-acre parcel of

Central Oregon Pumice mining claim (same view as previous photo), while in operation. Subsequent recontouring and revegetating during reclamation have led to the reestablishment of productive, self-sustaining systems.

land had been wholly disturbed by mining prior to 1972. Thus, the site was exempt from the Oregon Mined Land Reclamation Act, and the reclamation that was completed there was voluntary under state law.

By developing improvements in its operation, Central Oregon Pumice had been able to reenter this older mine area in the early 1980's and continue commercial production of pumice that had not been usable before because of its high moisture content. This production was then combined with reclamation.

The reclamation began with backfilling the 50-ft-deep excavation with volcanic ash. Before the final recontouring, the area was left idle for one year to allow for differential settling of the backfill. In the spring of 1986, the reclaimed area was seeded with crested wheatgrass and a pasture mix, and weedy species, primarily woolly mullein, were removed by hand.

Central Oregon Pumice reports that the reclaimed area shows the same degree of intensive deer usage as other reclaimed areas in the vicinity. Up to 50 deer at a time have been observed on this 24-acre parcel. The reclaimed grassy areas provide open spots that are favored by grazing wildlife. The surrounding vegetation is denser, consisting of lodgepole and Ponderosa pine with an understory of bitterbrush, rabbitbrush, and sagebrush.

Because of the date of the original disturbance of the area, this reclamation effort was completed without topsoil replacement. The topsoil is now salvaged and stockpiled separately for reclamation on the new mine areas. □

Earthquake hazards workshop successfully completed

The Oregon Department of Geology and Mineral Industries was pleased to host the National Earthquake Hazard Reduction Program's *1989 Workshop on Earthquake Hazards in the Portland/Puget Sound Areas* in Portland during the last week in March. The workshop was sponsored jointly by the U.S. Geological Survey (USGS), Federal Emergency Management Agency (FEMA), Oregon Emergency Management Department (EMD), Washington Department of Emergency Management (DEM), and Washington Department of Natural Resources (DNR). The purpose of the workshop was to bring together geoscientists, engineers, planners, emergency managers, businessmen, insurers, and local government officials to discuss the rapidly evolving changes in the understanding of earthquake hazards in the region.

Over 200 participants were involved in two days of presentations and discussions and a well-attended poster session. John Nance, popular author of *On Shaky Ground*, a book about earthquake hazards in America, presented a luncheon address. Finally, 60 participants went on a rainy field trip to the Oregon coast where they viewed evidence for past great earthquakes—and discovered new evidence in the process!

Although much attention was focused on the possibility of "the big one," a megathrust earthquake on the Cascadia subduction zone, participants also discussed the much better defined hazards from known seismic zones in the Puget Sound and in Portland. They generally agreed that the hazard was greater than had been previously considered and that both metropolitan areas are very poorly prepared for earthquakes. Rob Wesson, chief of the USGS Office of Volcanoes, Earthquakes, and Engineering, talked about the increased understanding of earthquake hazards in the area and summarized by saying, "The news is not good." Wesson stated that "If the earthquake that is argued to be possibly associated with this subduction zone is indeed realistic, then the earthquake hazard in Portland due to the Cascadia subduction zone is comparable to the earthquake hazard in Los Angeles due to the San Andreas Fault."

—Ian Madin, Oregon Department of Geology and Mineral Industries

OIL AND GAS NEWS

ARCO drills Clatsop County wildcat

During March, ARCO drilled the Oregon 21-33-86 well, located in sec. 33, T. 8 N., R. 6 W., about 10 mi northwest of the Mist Gas Field. The well was drilled to a total depth of 5,895 ft and was abandoned as a dry hole. No details have been released on the well.

Two-state task force on OCS leasing formed

A task force has been formed to advise the Secretary of the Interior on issues related to potential outer continental shelf (OCS) oil and gas leasing. The Pacific Northwest Outer Continental Shelf Task Force consists of J. Lisle Reid (Minerals Management Service), David McCraney (State of Washington), Gail Achterman (State of Oregon), James Harp (Northwest Indian Fisheries Commission), and Gordon HighEagle (Columbia Intertribal Fish Commission). The task force met for the first time on March 27, 1989.

The initial task will be to assist in the development of the environmental studies program for the Washington-Oregon OCS region. The Minerals Management Service, which conducts environmental studies for all OCS regions, will work with the task force in planning and implementing the studies. The task force will recommend areas to be deferred from the 1992 lease sale (if held) and will specify which environmental studies should be completed before a Draft Environmental Impact Statement is issued.

Correction on NWPA symposium announcement

The 1989 spring field symposium of the Northwest Petroleum Association (NWPA) will be held May 18-19, in **Leavenworth**, Washington (not Spokane, as erroneously announced at this place in the January issue). Contact person for additional information is Phil Brogan, 1426 NW Harmon Blvd., Bend, Oregon 97701; phone (503) 382-0560.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
420	ARCO Columbia Co. 34-28-65 36-009-00249	SW¼ sec. 28 T. 6 N., R. 5 W. Columbia County	Application; 1,930.
421	ARCO Columbia Co. 42-32-74 36-009-00250	NE¼ sec. 32 T. 7 N., R. 4 W. Columbia County	Application; 1,750.
422	ARCO CER 24-18-64 36-049-00251	SW¼ sec. 18 T. 7 S., R. 4 W. Morrow County	Application; 1,675.
423	ARCO CER 41-16-64 36-009-00252	NE¼ sec. 16 T. 6 N., R. 4 W. Columbia County	Application; 2,375.
424	ARCO Hamlin 33-17-65 36-009-00253	SE¼ sec. 17 T. 6 N., R. 5 W. Columbia County	Application; 2,980.
425	ARCO CER 23-22-64 36-009-00254	SW¼ sec. 22 T. 6 N., R. 4 W. Columbia County	Application; 1,330.

□

ABSTRACT

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that, we feel, are of general interest to our readers.

STRATIGRAPHIC AND GEOCHEMICAL EVOLUTION OF THE GLASS BUTTES COMPLEX, OREGON, by Richard L. Roche (M.S., Portland State University, 1987), 99 p.

The Glass Buttes complex lies at the northern margin of the Basin and Range Province in central Oregon and is cut by the northwest-trending Brothers fault zone. An older acrystalline volcanic sequence of high-silica rhyolites (>75 percent SiO_2) forms a broad platform composed of domes and flows with minor pyroclastic deposits. The high-silica rhyolite sequence is divided on the basis of texture into (1) zoned flows and domes, (2) obsidian flows, (3) felsite flows, and (4) biotite-phyric flows and domes. Stratigraphic relations indicate that high-silica rhyolite units in the western part of the complex overlie those to the east. K-Ar age determinations for the sequence range from 5.03 to 7.7 m.y. Geochemical trends within the sequence are characteristic of highly evolved magmas. The majority of the elements analyzed within the Glass Buttes high-silica rhyolite sequence fall into two groups that display similar behavior: (1) Sc, Rb, Cs, Sm, Tb, Yb, Lu, Ta, Th, U, and (2) Mg, Ca, Ti, Fe, Co, Ba, La, Ce, Nd, Eu, P. Elements within each group generally show positive correlations with each other, but negative correlations with elements of the other group. The variations between the two groups reflect the chemical stratification present within the high-silica rhyolite magma chamber prior to the eruption of the sequence. The presence of biotite phenocrysts within the sequence may indicate that the high-silica rhyolites were erupted from a relatively shallow magma chamber.

The vent locations of a younger volcanic sequence of rhyolites and rhyodacites are strongly controlled by structure. Vents are aligned along the trend of the Brothers fault zone. The petrology and geochemistry of the sequence indicate that it is not genetically related to the high-silica rhyolite sequence of volcanism. The rocks are phyric and contain various proportions of plagioclase (andesine-labradorite), hornblende, quartz, biotite, and ortho- and clinopyroxene phenocrysts. Phenocrysts range up to 40 percent of the rock volume. There are large variations in the concentrations of Fe, Mg, Ca, Ti, Sc, Co, Cr, and Eu among the different rhyolite and rhyodacite flows, indicating that the different flows represent distinct, but genetically related, magma batches.

Basaltic volcanism occurred throughout the silicic eruptive sequence. Several of the basalt flows erupted within the Glass Buttes complex show petrographic and geochemical evidence of contamination by rocks of the high-silica rhyolite sequence. The intrusion of basaltic magma into the crust is believed to have provided the heat source for the partial melting of crustal materials, leading to the generation of the silicic magmas. □

Mineralogical Symposium features zeolites

The Pacific Northwest chapter of the Friends of Mineralogy will hold its 15th Annual Mineralogical Symposium from Friday, September 29, through Sunday, October 1, 1989, at the Executive Motor Inn in Tacoma, Washington. Featured subject of the symposium will be zeolites.

The three-day program will present approximately a dozen speakers who will discuss zeolites under a variety of aspects, including the formal presentation of two new zeolites.

The symposium program will also include a banquet dinner, a benefit auction as part of the Saturday evening program, micromount tables and trading sessions, and competitions for the best photos and slides and the best self-collected minerals.

In addition to displays of the Friends of Mineralogy, five major dealers from the United States and Canada will have displays on the show floor, and several dozen satellite dealers will be located in guest rooms of the Executive Inn. Displays and dealer shows will be open to the public Friday and Saturday evenings with an admission charge of $2.

More information on registration and program is available through John Lindell, 3311 NW 74th, Seattle, WA 98117. Satellite-dealer information may be obtained from Ray Lasmanis, #155, 910 Sleater Kinney SE, Lacey, WA 98503.

—Friends of Mineralogy announcement

NWPA holds symposium

The Northwest Petroleum Association (NWPA) will hold its fifth annual symposium at Leavenworth, Washington, on May 18-20, 1989. The hydrocarbon potential of the Columbia Basin, Oregon and Washington, will be addressed with emphasis on potentially productive Eocene and Oligocene sediments underlying the Columbia River basalts. The symposium schedule includes one day of technical-paper presentation and two days of field trips in the Chiwaukum graben and the Roslyn "basin."

Additional information is available from Phil Brogan, 1426 NW Harmon Blvd., Bend, Oregon 97701, phone (503) 382-0560.

—NWPA news release

GRC announces annual meeting

The Geothermal Resources Council (GRC) will hold its 1989 Annual Meeting October 1-4 at the El Rancho Tropicana Hotel in Santa Rosa, California, and has issued a call for papers for this meeting.

Santa Rosa is the closest major city to The Geysers. The geothermal field is celebrating its third decade of operation, and the emphasis of the meeting will therefore be on the technological development, production history, and regulatory and environmental issues that have evolved from this activity.

For the first time, a trade show will be held in conjunction with the meeting. It will be developed and managed by the National Geothermal Association and will consist of the usual indoor exhibits and an outdoor Tech Yard.

Field trips will concentrate on The Geysers Geothermal Field and cover at least six different subjects on separate trips. On the subject of geothermal direct use, a special one-day field trip has been scheduled to Calistoga in the Napa Valley and to a geothermal-greenhouse project in Lake County.

Papers are solicited in the following areas:

- Exploration—geology, geophysics, geochemistry, and hydrology
- Drilling and well design—shallow and deep
- Field development—civil and geologic engineering
- Production technology—pipe lines and production facilities
- Reservoir engineering—production-well testing, injection, and modeling
- Power generation and plant operation—small and large, low- and high-temperature, construction and power transmission
- Legal and institutional aspects
- Economics, financing, and marketing
- Environmental aspects
- Direct use—agri- and aquaculture, manufacturing, and space heating

*(Continued on page 70, **GRC**)*

Reclamation of exploratory drill sites in Oregon

by Dan E. Wermiel, Petroleum Geologist, Oregon Department of Geology and Mineral Industries

INTRODUCTION

Reclamation refers to the restoration of a drill site to a condition that is of beneficial use to the surface owner. By definition, reclamation of a surface operation means the use of procedures reasonably designed to minimize as much as is practical the disruption from the surface operation and to provide for the rehabilitation of any surface resources adversely affected by such surface operations through rehabilitation of plant cover, soil stability, water resources, and other measures appropriate to the subsequent beneficial use of such reclaimed lands. In any oil and gas exploratory drilling operation that is done in Oregon, the Oregon Department of Geology and Mineral Industries (DOGAMI) has regulatory authority to ensure that reclamation of a drill site is done in a manner deemed acceptable to both this agency and to the surface owner.

Figure 1. A typical drill site in Oregon involves about 1 acre of land. This is the ONGD well IW 33c-3 at Mist Gas Field drilled during 1987.

EXPLORATORY DRILL SITES: IMPACT

When an oil or gas well is proposed in Oregon, an operator submits an application that includes a plan of operation to DOGAMI. When this applicant receives a permit to drill, the existing reclamation requirements by the State of Oregon are required to be followed. Part of the application requirement is for the operator to post a $25,000 individual well bond or $150,000 blanket bond. This bond will not be released until all operations, including reclamation, are concluded in a satisfactory manner.

In general, a drill site in Oregon disturbs about 1 acre of land and is rectangular in shape (Figure 1). It is graded flat, with a sump on one side. The drilling operation itself usually takes about two weeks or less, at which time the drill site is reclaimed, should the well be a dry hole. If the well is successful in finding oil and gas, the site remains in use for the lifetime of the well. In either case, the drilling and production use of a site are temporary, after which the site is reclaimed.

RECLAMATION OF DRILL SITES

In Oregon, oil and gas drilling operations have been primarily in the Mist Gas Field area since its discovery in 1979. The field is located in Columbia County and is in a forest area. The drilling operations have proved to be compatible with the forest use operations. The timber companies have benefited economically by receiving royalty payments from gas production on their lands and have found the drill sites to be useful in their forest harvest operations. This compatible balance of gas drilling and forest use has influenced the reclamation decisions of drill sites at Mist Gas Field. In most cases, when a well is abandoned, the drill site is returned to its original forest condition for replanting (Figure 2). If the site had gravel placed on it during construction, the gravel is scraped and removed for use on roads, and the top soil is replaced before replanting.

In some cases, where the drill sites are located in areas of old trees scheduled for future cutting, the site is left for use as a landing during tree harvesting. It will then be replanted upon completion of the cutting operations. This reclamation method fits well with forest use planning in that drilling operations and forest operations coexist in a compatible relationship. Compatibility of drilling and surrounding land use exists at the Mist Gas Field and other locations throughout Oregon, including areas of agricultural use.

Figure 2. This reclaimed drill site is for the Leadco well CC-Jackson 22-17 at Mist Gas Field. This abandoned well was drilled on Cavenham Forest Industry land during August 1987.

SUMMARY

Reclamation of drill sites provides restoration of the affected land to a beneficial use. In Oregon, a drilling operation generally temporarily affects about a 1-acre area. Subsequent reclamation required of the operator must be acceptable to both DOGAMI and the surface owner. In forest use areas, such as Mist Gas Field in Columbia County, the drilling operations have proved to be compatible with forest operations. Drill sites are replanted for forest use, unless the owner desires to use the site as a landing during tree cutting operations, after which it will be replanted. Compatibility of drilling operations and surrounding land use also exists in agricultural use areas. □

BOOK REVIEW

by Paul F. Lawson, mineral collector and retired Supervisor, Oregon Department of Geology and Mineral Industries, Mined Land Reclamation Program

Crystals and Minerals: A Family Field Collecting Guide for Northwestern Oregon and Southwestern Washington, by Jon Gladwell, 1989. Price $7.95. 43 pages, 5½ by 8½ inches. Available from the author at 2018 East Sixth Street, Vancouver, Washington 98663.

This well-organized guidebook to sixteen sites in the subject area has a number of outstanding features. All mineral-collecting guides should have these features, but unfortunately few do to an equal degree. I am referring to the author's discussion of tools and equipment, his rating of ease of access to sites, and recommended equipment for each site. Also, he tells the reader what minerals can be expected at each site and by his line drawings shows the newcomer what to look for. A trip log, an individual site map, and references to the appropriate U.S. Geological Survey quadrangle maps are provided for each site. The author also provides a brief resume of each site and conditions attendant to it. Commendably, he summarizes safety considerations for each site where appropriate. It would have been desirable to mention that poison oak is abundant (and very virulent to some persons) in timber or brush in the Kalama area and in the Columbia River Gorge. Additionally, at points east of Beacon Rock, scorpions are numerous but not usually aggressive.

As in most guides, a few areas in this one should have a second look. For example, at the Kalama site, page 12, unless the Washington State Police have changed their attitude, you are likely to get a warning or a citation if you are collecting within the right-of-way along Interstate I-5. Their rationale seems to be that any activity on the right-of-way is a distraction to motorists.

By reference to the distance to Kelley Creek, page 34, the author appears to suggest that Kelley Creek is not an appropriate name for the gismondine location. If this is the case, and since the Kelley Creek name almost certainly has no official status in relation to this site, why perpetuate it in print? More importantly, the author refers to abundant gismondine at the road level, when, unless there have been recent additional finds, the supply of gismondine at the road level appears to have been about exhausted.

For the Boulder Creek site, page 36, the author indicates a specific copy of the *Ore Bin* for directions, then provides a log of the area for those collectors who do not have the *Ore Bin*. If the collector does not have the *Ore Bin*, how does he or she get to checkpoint 00.00?

Few of the sites listed are new to collectors who have been active in the area for several years. The book does not include some sites it might. On the other hand, few, or perhaps none, of these sites have been located or described as well in any field guide to date. This guide should be useful to the family, as targeted, to beginning collectors, and to collectors new to the area. Whether the value of this guide justifies its price is a decision each prospective purchaser must make for himself or herself. □

AASG publishes history of State Surveys

The Association of American State Geologists (AASG) has recently published *The State Geological Surveys—A History*, a compilation of the histories of state geological surveys in the United States.

Edited by retired Pennsylvania State Geologist Arthur A. Socolow, the illustrated, hard-covered, 499-page book contains descriptions of the history, organization, and functions of the 50 State Geological Surveys. Each state is represented in an individual chapter prepared by the respective Survey.

This comprehensive volume was produced in recognition of the major role the State Geological Surveys have played in geologic mapping and research accomplished in the United States over the past 150 years. Diverse in name, size, and detailed functions, the 50 State Surveys, of which more than 30 originated over 100 years ago, have the basic responsibility to delineate the geologic framework and the geologic resources of their states.

The State Geological Surveys—A History may be ordered from the Geological Survey of Alabama, P.O. Box 0, Tuscaloosa, AL 35486. The price is $20 and includes shipping. Checks are to be made payable to the AASG. *—From AASG news releases*

USBM issues state-by-state report on mineral production

The U.S. Bureau of Mines (USBM) has released a report on nonfuel mineral production in 1988. The new 187-page book, *State Mineral Summaries 1989*, is the earliest government publication to furnish estimates covering annual nonfuel mineral production in each of the 50 states. It is also the first USBM release of the state mineral summaries in one volume and is offered in addition to the usual, separately printed, individual state summaries.

Nonfuel minerals include all minerals except coal, petroleum, and uranium. The reported figures are preliminary estimates, usually based on the data from nine months. Final mineral-production information will be published at a later date in the USBM *1988 Minerals Yearbook*.

According to the preliminary statistics for 1988, California led the nation in nonfuel mineral production for the fifth year in a row, recovering minerals worth an estimated $2.85 billion, a 12-percent increase over 1987. Principal minerals in California were cement, sand and gravel, and boron. Only second-ranked Arizona produced a similar value, $2.83 billion, mainly with copper, sand and gravel, and cement. Oregon ranks 39th with an estimated production value of $169 million, principally from crushed stone, sand and gravel, and cement.

In the new volume, the summaries have been expanded to provide more information on mineral activities in every state. Each summary includes sections on such matters as employment, exploration, environmental issues, government legislation and programs, and a review of each mineral produced in the state.

The new document is designed to be a companion volume to another USBM document, *Mineral Commodity Summaries 1989*, a preliminary report, by commodity, on the production of 82 nonfuel minerals during the previous year.

Single copies of both preliminary reports may be obtained without charge from the Publications Distribution Section, U.S. Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236; phone (412) 892-4338. *—USBM news release*

(GRC, continued from page 68)

All papers will be considered for publication in the *Transactions*; approximately 70 will be selected for oral presentation and approximately 30 for presentation in the poster session. Final deadline for submission is June 9, 1989. Papers must be delivered to the Geothermal Resources Council, 2121 Second Street, Suite 101A, Davis, California, phone (916) 758-2360, or mailed to P.O. Box 1350, Davis, CA 95617-1350; Telex 882410; Fax (916) 758-2839.

For the annual photography contest, submission deadline is September 1, 1989. Chairman and contact person is Nic Nickels, Eastman Christensen, 3636 Airway Place, Santa Rosa, CA 95403; phone (707) 523-1751.

—From GRC announcement

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

	Price	No. copies	Amount
GMS-5. Geologic map, Powers 15-minute quadrangle, Coos and Curry Counties. 1971	3.00		
GMS-6. Preliminary report on geology of part of Snake River canyon. 1974	6.50		
GMS-8. Complete Bouguer gravity anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-9. Total-field aeromagnetic anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-10. Low- to intermediate-temperature thermal springs and wells in Oregon. 1978	3.00		
GMS-12. Geologic map of the Oregon part of the Mineral 15-minute quadrangle, Baker County. 1978	3.00		
GMS-13. Geologic map, Huntington and part of Olds Ferry 15-min. quadrangles, Baker and Malheur Counties. 1979	3.00		
GMS-14. Index to published geologic mapping in Oregon, 1898-1979. 1981	7.00		
GMS-15. Free-air gravity anomaly map and complete Bouguer gravity anomaly map, north Cascades, Oregon. 1981	3.00		
GMS-16. Free-air gravity anomaly map and complete Bouguer gravity anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-17. Total-field aeromagnetic anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-18. Geology of Rickreall, Salem West, Monmouth, and Sidney 7½-min. quads., Marion/Polk Counties. 1981	5.00		
GMS-19. Geology and gold deposits map, Bourne 7½-minute quadrangle, Baker County. 1982	5.00		
GMS-20. Map showing geology and geothermal resources, southern half, Burns 15-min. quad., Harney County. 1982	5.00		
GMS-21. Geology and geothermal resources map, Vale East 7½-minute quadrangle, Malheur County. 1982	5.00		
GMS-22. Geology and mineral resources map, Mount Ireland 7½-minute quadrangle, Baker/Grant Counties. 1982	5.00		
GMS-23. Geologic map, Sheridan 7½-minute quadrangle, Polk/Yamhill Counties. 1982	5.00		
GMS-24. Geologic map, Grand Ronde 7½-minute quadrangle, Polk/Yamhill Counties. 1982	5.00		
GMS-25. Geology and gold deposits map, Granite 7½-minute quadrangle, Grant County. 1982	5.00		
GMS-26. Residual gravity maps, northern, central, and southern Oregon Cascades. 1982	5.00		
GMS-27. Geologic and neotectonic evaluation of north-central Oregon. The Dalles 1°x2° quadrangle. 1982	6.00		
GMS-28. Geology and gold deposits map, Greenhorn 7½-minute quadrangle, Baker/Grant Counties. 1983	5.00		
GMS-29. Geology and gold deposits map, NE¼ Bates 15-minute quadrangle, Baker/Grant Counties. 1983	5.00		
GMS-30. Geologic map, SE¼ Pearsoll Peak 15-minute quadrangle, Curry/Josephine Counties. 1984	6.00		
GMS-31. Geology and gold deposits map, NW¼ Bates 15-minute quadrangle, Grant County. 1984	5.00		
GMS-32. Geologic map, Wilhoit 7½-minute quadrangle, Clackamas/Marion Counties. 1984	4.00		
GMS-33. Geologic map, Scotts Mills 7½-minute quadrangle, Clackamas/Marion Counties. 1984	4.00		
GMS-34. Geologic map, Stayton NE 7½-minute quadrangle, Marion County. 1984	4.00		
GMS-35. Geology and gold deposits map, SW¼ Bates 15-minute quadrangle, Grant County. 1984	5.00		
GMS-36. Mineral resources map of Oregon. 1984	8.00		
GMS-37. Mineral resources map, offshore Oregon. 1985	6.00		
GMS-38. Geologic map, NW¼ Cave Junction 15-minute quadrangle, Josephine County. 1986	6.00		
GMS-39. Geologic bibliography and index maps, ocean floor and continental margin off Oregon. 1986	5.00		
GMS-40. Total-field aeromagnetic anomaly maps, Cascade Mountain Range, northern Oregon. 1985	4.00		
GMS-41. Geology and mineral resources map, Elkhorn Peak 7½-minute quadrangle, Baker County. 1987	6.00		
GMS-42. Geologic map, ocean floor off Oregon and adjacent continental margin. 1986	8.00		
GMS-43. Geologic map, Eagle Butte and Gateway 7½-min. quads., Jefferson/Wasco Co. 1987 ....$4.00; as set with GMS-44 & -45.	10.00		
GMS-44. Geologic map, Seekseequa Junction/Metolius Bench 7½-min. quads., Jefferson Co. 1987 .....$4.00; as set with GMS-43 & -45.	10.00		
GMS-45. Geologic map, Madras West and Madras East 7½-min. quads., Jefferson County. 1987 ......$4.00; as set with GMS-43 & -44.	10.00		
GMS-46. Geologic map, Breitenbush River area, Linn/Marion Counties. 1987	6.00		
GMS-47. Geologic map, Crescent Mountain area, Linn County. 1987	6.00		
GMS-48. Geologic map, McKenzie Bridge 15-minute quadrangle, Lane County. 1988	8.00		
GMS-49. Map of Oregon seismicity, 1841-1986. 1987	3.00		
GMS-50. Geologic map, Drake Crossing 7½-minute quadrangle, Marion County. 1986	4.00		
GMS-51. Geologic map, Elk Prairie 7½-minute quadrangle, Marion/Clackamas Counties. 1986	4.00		
GMS-53. Geology and mineral resources map, Owyhee Ridge 7½-minute quadrangle, Malheur County. 1988	4.00		
GMS-54. Geology and mineral resources map, Graveyard Point 7½-minute quad. Malheur/Owyhee Counties, Oregon/Idaho. 1988	4.00		

BULLETINS

	Price	No. copies	Amount
33. Bibliography of geology and mineral resources of Oregon (1st suppplement, 1937-45). 1947	3.00		
35. Geology of the Dallas and Valsetz 15-minute quadrangles, Polk County (map only). Revised 1964	3.00		
36. Papers on Foraminifera from the Tertiary (v.2 [parts VI-VIII] only). 1949	3.00		
44. Bibliography of geology and mineral resources of Oregon (2nd supplement, 1946-50). 1953	3.00		
46. Ferruginous bauxite deposits, Salem Hills, Marion County. 1956	3.00		
53. Bibliography of geology and mineral resources of Oregon (3rd supplement, 1951-55). 1962	3.00		
61. Gold and silver in Oregon. 1968	17.50		
65. Proceedings of the Andesite Conference. 1969	10.00		
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