CALIFORNIA GEOLOGY

MAY 1989

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INSIDE:

Davenport Cement Plant

CALIFORNIA DEPARTMENT OF CONSERVATION

Division of Mines and Geology

Understanding California's Geology

Our Resources – Our Hazards

CALIFORNIA GEOLOGY

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In This Issue

Cover: Oblique aerial photo of the Davenport portland cement plant on the central coast of California, Santa Cruz County, circa late 1970s. Since this photo was taken, many changes have been made at this plant. Limestone and shale from nearby quarries are used to make cement at the plant. California leads all other states in the production of cement and concrete aggregate which are necessary commodities for our industrialized society. The Davenport cement plant has been in nearly continuous operation since 1906. An article about how portland cement is manufactured at the newly remodeled Davenport plant starts on page 99. *Photo courtesy of Pacific Cement and Aggregates Division, Lone Star Cement Corporation.*

South Coast Geological Society Call For Papers

South Coast Geological Society will conduct a fall field trip along the San Andreas fault from the vicinity of Cajon Pass into the Carrizo Plain. The trip will take place in October 1989. This is a call for papers to be published in the guidebook. Topics for the papers need not be confined to the area of the fault covered by the field trip.

Submit papers by August 15, 1989, to Joan Baldwin, South Coast Geological Society, P.O. Box 10244, Santa Ana, California 92711. For further information, call Joan Baldwin at (714) 839-8664 or John Foster at (714) 727-3223.

Clay Minerals Society Conference

California State University, Sacramento, will sponsor the 26th Annual Clay Mineral Society meeting and the 38th Annual Clay Conference to be held September 23-28, 1989 in Sacramento, California.

The programs will include:

Symposia on Clays as Containment Barriers and Clays as Fundamental and Mixed-Layer Particles;
General Technical Sessions on Clay Science and Technology;
Workshop on Rheology of Clay/Water Systems; and
Field Trips (1) Chlorite Series of Flagstaff Hill; (2) Kaolinite Deposits of the Ione Formation; and (3) Commercial Bentonite Deposits of California and Nevada.

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DAVENPORT CEMENT PLANT

Santa Cruz County, California

By

DON DUPRAS, Geologist
Division of Mines and Geology

This is the third article in a series on concrete and cement (see January 1989 and February 1989 issues). Portland cement has been called "the magic powder of civilization" because of its fundamental importance to the quality of life. It is indispensable in constructing modern homes, schools, skyscrapers, bridges, factories, airports, dams, and highways. The Davenport cement plant was examined because (1) the remodeled operation typifies modern cement production processes; (2) it is one of the oldest cement manufacturing facilities in California; and (3) it illustrates the important contribution industrial mineral mining and processing gives to the citizens of California. State-of-the-art manufacturing plants, like the one at Davenport, California, ensure that abundant, high-quality cement is available at reasonable cost. . . . *editor.*

INTRODUCTION

Portland cement, the fundamental binding ingredient of concrete, is made from a specific mix of calcareous material, such as limestone or chalk, and from alumina-, iron-, and silica-bearing materials, such as clay, shale, iron ore, and laterite. The manufacturing process of portland cement generally consists of grinding the raw materials, blending them in specific proportions, and burning the mixture in a large rotary kiln at high temperatures. The raw materials convert first to sinter,* then partially fuse into clinker balls. The clinker is cooled, mixed with about 5 percent gypsum to control setting time, then pulverized into a fine powder. The resulting gray portland cement powder can then be mixed with the proper proportions of water, sand, and gravel to make durable concrete.

HISTORY OF CEMENT PRODUCTION IN CALIFORNIA

As a result of the California gold rush and the later population influx, San Francisco grew from a relatively small town of about 40,000 in 1850 to 342,000 by 1900. The rapid population growth of San Francisco and the surrounding communities in the San Francisco Bay region during the late 1800s resulted in a constantly increasing demand for building materials of all types. Because of the cost effectiveness and versatility of portland cement, its consumption in the San Francisco area increased from 12,000 barrels in 1859 to 100,000 barrels per year by 1865 (Bowen, 1957).

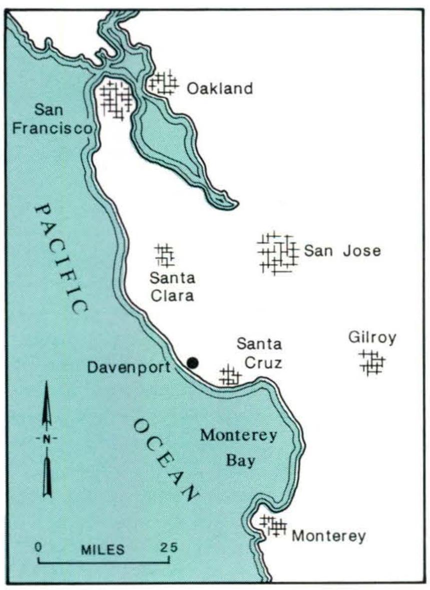

Figure 1. Location of the Davenport portland cement plant, Santa Cruz County, California.

To satisfy demand, portland cement was brought in by ship over the long treacherous route around Cape Horn of South America. Most of the portland cement used in California before 1877 was imported from England. Because of competition from England and other European countries, there was only modest production of cement in California prior to 1891.

The first California plant to produce portland cement was built in 1877 by the California Portland Cement Company in the town of Santa Cruz, Santa Cruz County. The primary ingredients for the cement — lime, silica, and alumina — were available from local limestone and shale deposits. Limestone was quarried in the vicinity of present-day Wagner Park and shale was quarried from pits at the head of Walnut Avenue in Santa Cruz. As a consequence of European competition, plant operations lasted only a few years (Bowen, 1957).

DAVENPORT CEMENT PLANT

During the early 1900s, three factors led to the development of the first large cement plant on the west coast:

(1) The population of San Francisco and other coastal cities on the west coast would continue to grow rapidly throughout the early 1900s;
(2) Hawaii became a United States territory in 1900 and the U.S. Navy soon began construction of the extensive Pearl Harbor complex; and
(3) President Theodore Roosevelt signed an agreement with the government of Panama in 1903 to build and operate the Panama Canal.

Massive tonnages of cement would be needed for these projects (Lonestar, 1981).

Original Plant

These historic events spurred the decision by the Standard Portland Cement Company to build a cement manufacturing plant near San Francisco. The proposed site was 12 miles northwest of Santa Cruz, about 70 miles southeast of San Francisco (Figure 1). The site afforded an abundance of high-quality limestone and shale, and provided convenient access to ocean transport. Construction of the plant began in October 1905. Men and mules worked ten hours a day, six days a week to build the plant.

* When high enough temperatures are reached the materials begin to agglomerate or fuse together in a process called sintering.

The town of Davenport, southeast of the plant on the east side of Highway 1, was largely built by the Standard Portland Cement Company, which later became the Santa Cruz Cement Company. The town was named after the adjacent whaling station of Davenport Landing that had been established in the 1850s by Captain John P. Davenport (Gudde, 1969).

While the plant was under construction, the April 14, 1906 earthquake and fire devastated much of the city of San Francisco. Thirty thousand buildings in 497 neighborhood blocks were completely destroyed. Reconstruction began almost immediately and work on the cement plant at Davenport was accelerated. The first kiln at the plant began production before the end of 1906.

When the Davenport plant was totally finished on May 17, 1907, it was the second largest cement facility in the United States. As a result of the massive reconstruction effort after the 1906 quake and the need for cement, plant construction was accelerated and completed more than a year ahead of schedule. Many of the reconstructed buildings, streets, sidewalks, and other concrete structures visible today in the San Francisco Bay region were made with cement manufactured at Davenport.

Thousands of tons of cement from the Davenport plant were used in constructing Pearl Harbor and the Panama Canal. During World War II the first cement bulk-loading steamer in the world, the *S.S. Santacruzcement,* sailed from the ocean pier at Davenport to the Pacific Islands where Navy Seabees used the cement to construct harbors and airfields. The ship was lost during the war.

During the California building boom before and after the war, cement produced at the Davenport plant was used in many large construction projects in the San Francisco Bay area — Golden Gate Bridge, Oakland Bay Bridge, Candlestick Park, and many buildings on the San Francisco skyline and surrounding communities (Lonestar, 1981).

Photo 1. The remodeled Davenport cement plant, oblique aerial view toward the east. Highway 1 traverses left to right in front of the plant. Portland cement has been produced at this site since 1906. The whitish cut in the hills above the plant is the Bonny Doon shale quarry. Remains of the pier once used to load cement onto ships juts out into the Pacific Ocean. *Photos by RMC Lonestar and author.*

Remodeled Plant

During the 1970s plant supervisors decided to completely remodel the Davenport plant to make it more efficient. Three major considerations led to that decision:

(1) Fine cement dust from the plant blew over the surrounding community as it had since operations began in 1906. The dust was bothersome to the growing population of nearby farmers. Although newly developed methods of controlling air quality were available, the modifications required to improve air quality could not be implemented at the existing plant.
(2) Skyrocketing energy costs created by the oil crisis in the mid-1970s vastly reduced profits at the plant. Because energy is the single greatest cost of producing portland cement, less expensive, more efficient energy sources were needed to maintain the high quality of cement production at the plant.
(3) To survive in the highly competitive cement market, more efficient production methods were needed that would extend the valuable limestone reserves near the plant by many years, and would increase output per employee.

When the remodeled Davenport operation began production in August 1981, air pollution became almost non-existent, energy costs per barrel of cement were significantly decreased, and output per employee doubled (Photo 1; Figure 2). The plant is one of the most advanced cement manufacturing operations in the world and incorporates the latest technologies in raw materials processing, automation, pyroprocessing, and environmental controls (Photo 2).

Since the original Davenport plant began production in 1906, ownership has changed a few times. Past operators of the Davenport plant include Santa Cruz Cement, Pacific Cement and Aggregates, Lone Star Industries, and RMC Lonestar,* the current operator. In December 1987, RMC Lonestar, a major producer of cement, ready-mixed concrete, and aggregate in northern California, acquired a 20-year lease on the newly remodeled plant with an option to buy.

MINING

The two most significant raw materials in terms of tonnages used to make portland cement at the Davenport plant are limestone and shale. These ores are mined within a few miles of the plant and transported via conveyor belts to the plant. Smaller proportions of other essential raw materials needed to make cement include gypsum, laterite, and iron ore. These raw materials are mined elsewhere and shipped to the plant. Most of the energy for producing cement at Davenport is derived from low-sulfur bituminous coal mined near Price, Utah and shipped to the plant via rail. All raw materials are stockpiled at the plant until needed.

* The RMC abbreviation in RMC Lonestar means "ready-mixed concrete." RMC is based in Europe and is one of the largest concrete production firms in the world. RMC Lonestar is a northern California partnership between RMC and Lone Star Industries.

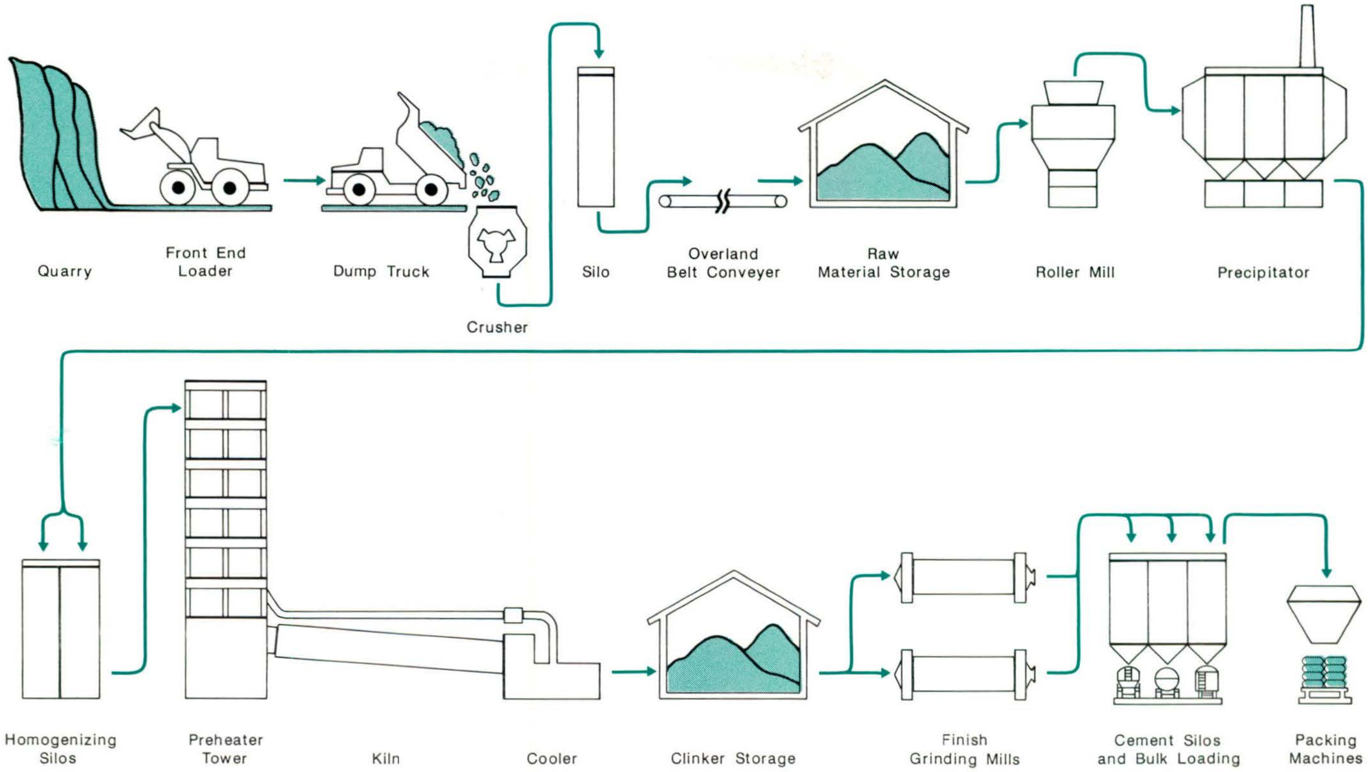

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Figure 2. Schematic material flow chart of the Davenport cement operation. This is a simplified diagram as though it were a straight-line process. *Adapted from Lonestar, 1981.*

Limestone

Portland cement incorporates about 65 percent lime (CaO), also called *quicklime,* which is derived from calcining limestone. Limestone is quarried at the Bonny Doon limestone quarry located about three miles southeast of the Davenport plant (Photo 3).

The pre-Cretaceous marine metalimestone at the Bonny Doon limestone quarry is composed of coarsely crystalline, white to pale-grey calcite that is generally free of magnesium carbonate (Fitch, 1931; Jennings and Burnett, 1968). The limestone has been altered and lenses of ore at the quarry site appear to have been metamorphosed to marble. Twin lamellae calcite crystals are commonly bent and fractured. Pockets and lenses of impure clayey limestone occur sporadically throughout the quarry and indicate geologically recent petrological alterations caused by in-situ weathering (Trask, 1926; Fitch, 1931).

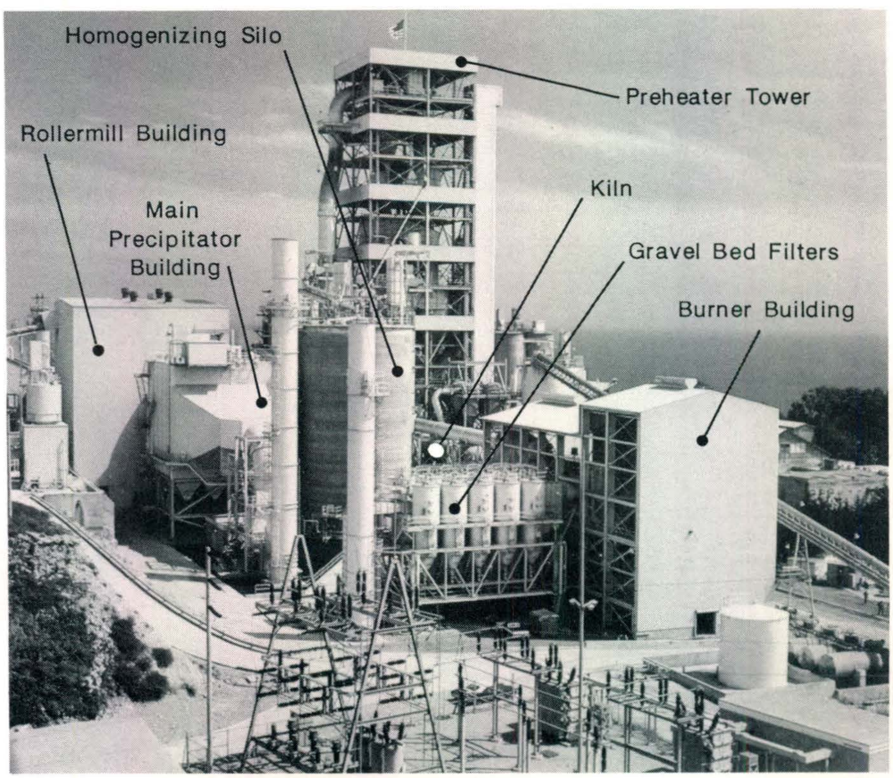


Photo 2. North side of the Davenport plant. Renovated in 1981, the plant now incorporates state-of-the-art cement manufacturing technologies in raw materials processing, automation, and pyroprocessing. The remodeled plant now has only one short kiln but produces nearly twice the capacity as the old plant that had three kilns. The new plant requires one-third less energy per ton of cement produced compared with the old one.

Photo 3. The Bonny Doon limestone quarry. The altered high-quality limestone is older than 136 million years and is an important natural resource. Limestone is the primary raw material used at the plant because portland cement is made from about 65 percent lime. The 40-foot-tall rig on the top bench of the quarry is used to drill the holes for blasting.

The conveyor system that transports the limestone and shale to the plant is covered with a concrete housing to control dust emissions (Photo 6). Limestone and shale are stored in a large building near the plant (Photo 7).

Iron Ore, Laterite, and Gypsum

The iron ore used at the plant is mined at Barth, Nevada then shipped to Davenport via rail. Laterite, a clay rich in aluminum oxides, is quarried at Ione, Amador County, California and transported by rail to the plant. Laterite is used primarily for its alumina content but also augments the silica requirement of portland cement. Gypsum is trucked to the plant from Antioch, California.

COMPUTERIZED CONTROL

Operations run 24 hours a day, seven days a week. All processing phases are constantly monitored so that when production modifications are required anywhere within the manufacturing process, a central computer automatically adjusts the system to assure quality production.

Mining operations at the quarry began in 1969 and the indurated rock is blasted free using millisecond delay blasting techniques to minimize shock. The ore is scooped up by front-end loader and dumped into a truck (Photo 4) which, in turn, unloads the ore into an impact crusher that can reduce boulders as big as a piano to pieces smaller than a softball. The crushed limestone is transported three miles by a series of conveyor belts to the main plant.

Shale

Mid-Miocene marine argillaceous shale is mined at the Bonny Doon shale quarry located a little over a mile east of the plant (Jennings and Burnett, 1968). The shale supplies silica (SiO_2) and some of the alumina (Al_2O_3) required to make portland cement. Cement is made from about 25 percent silica and alumina.

After the shale is ripped, it is placed by front-end loader onto trucks that dump it into a crusher. Crushed shale is then loaded onto the same conveyor belt system used to transport the limestone and transported to the plant (Photo 5).

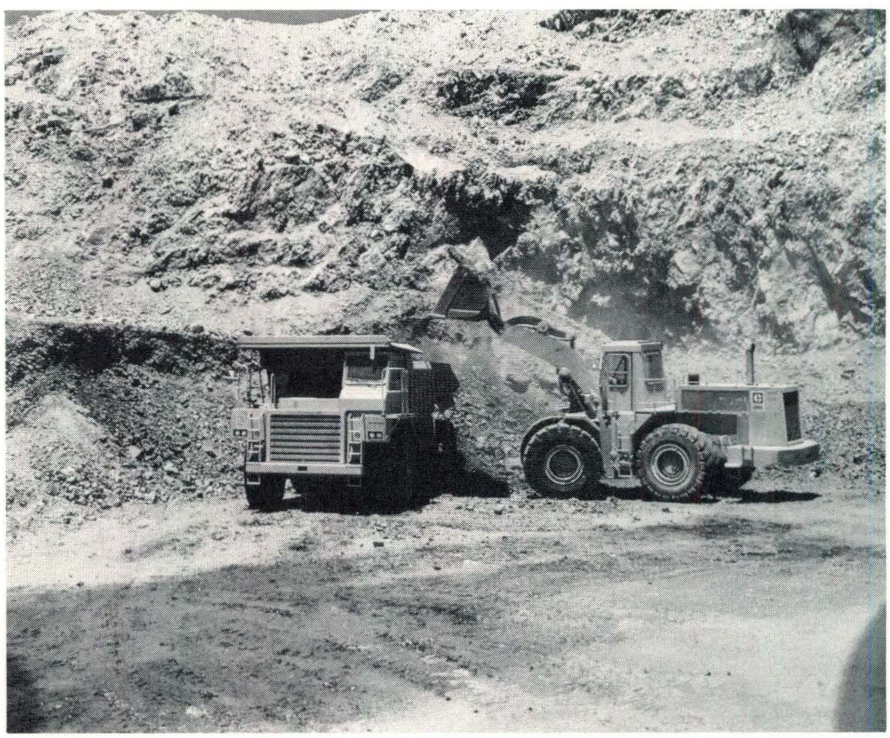
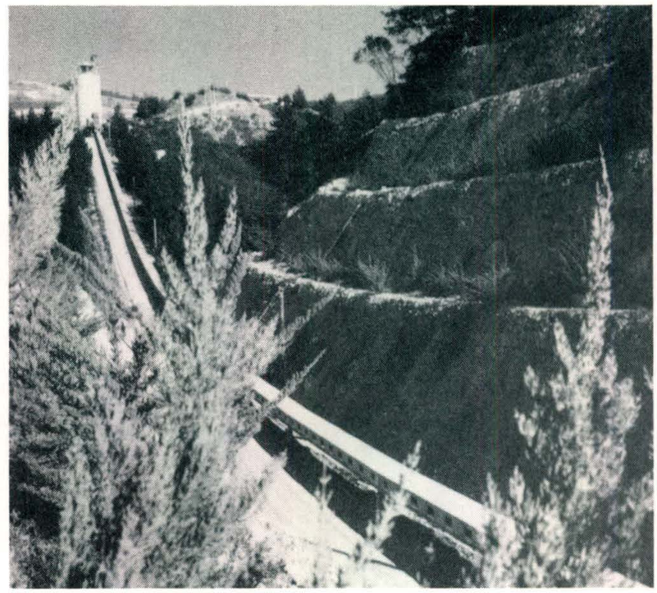


Photo 4. Mining operations are simple; a front-end loader scoops up the ore and dumps it into a truck; the truck then unloads the ore into a primary crusher. This mining method is used at the Bonny Doon shale and Bonny Doon limestone quarries.



▲ Photo 6. The conveyor belt system which transports limestone and shale from the quarries is housed in concrete to minimize dust emissions. Storage silo at the Bonny Doon limestone quarry is on the hill to the left.

◀ Photo 5. Conveyor and silo at the Bonny Doon shale quarry. The conveyor from the Bonny Doon limestone quarry is to the left of the silo. Main plant is in the distance.

Except for quarry and shipping operations, the entire production process at the Davenport plant is fully automated and under continuous computer control.

Microprocessors located throughout the manufacturing circuit are tied into the main computer by a coaxial cable. The main computer and laboratory are located in the control building. Control room operators monitor the entire manufacturing process and computer operations via control consoles in the central computer room (Photo 8).

The main computer, laboratory, and business services office are in the control building located at the entrance to the plant.

Photo 7. Warehouse building where the limestone and shale are stored. The Bonny Doon shale quarry, silo, and conveyor belt system are visible beyond the warehouse. When needed, the limestone and shale are transported by conveyor from the warehouse and processed.

▲

Photo 8. Computer consoles in the central control room display data combined with physical outlines of the processing equipment. This allows the control room personnel to monitor production. The entire manufacturing process except for quarry and shipping operations is fully automated and under continuous computer control. When a variation anywhere in the manufacturing process requires an adjustment, corrections are automatically signaled from the central control room.

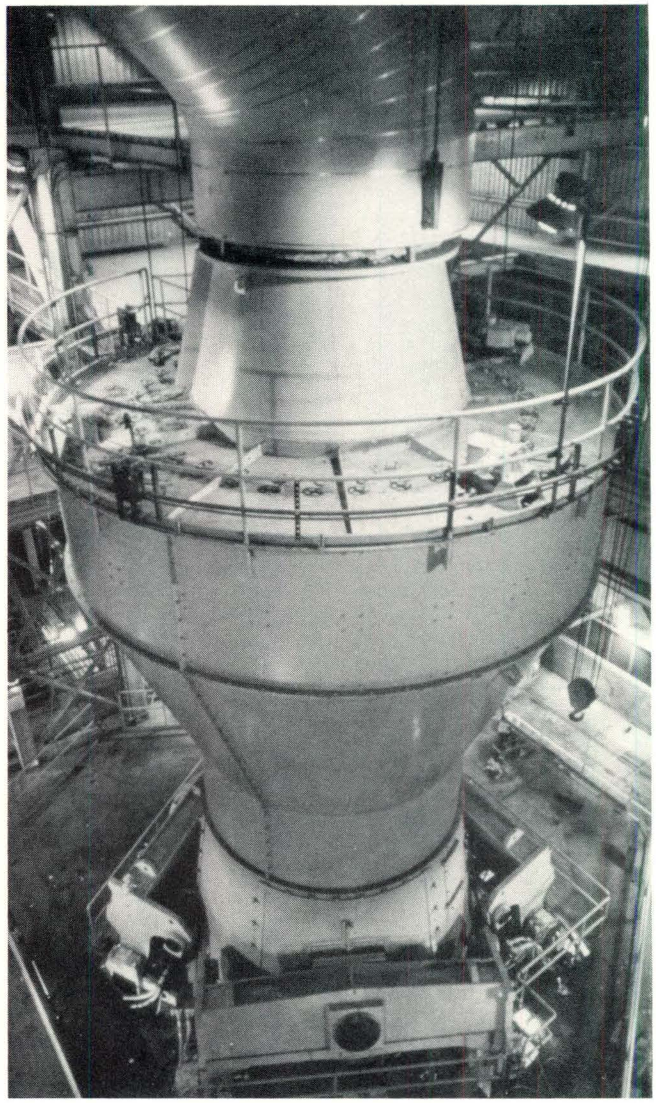


Photo 9. The giant roller mill combines drying, secondary crushing, fine grinding, and size classification operations of the raw materials in a single unit. The mill efficiently utilizes hot exhaust gas generated in the kiln system. Rock as big as four inches in diameter is ground to a powder the size of flour in the mill. The powder is then separated from the gas stream by the main precipitator and conveyed to two homogenizing silos. ▶

During the manufacturing process automated tests are performed at sites throughout the processing circuit to assure compliance with quality control specifications. As part of the automated control system, the computer-controlled on-line sampling and analyzing system constantly samples materials by an X-ray fluorescence spectrometer.* For example, if an iron deficiency is detected, additional iron ore is automatically added to make the correct blend. In addition to the computer-controlled on-line sampling and analyzing system, plant personnel sample and test the chemical and physical parameters of the materials in the laboratory to further ensure that the finished cement is of high quality (Lonestar, 1981).

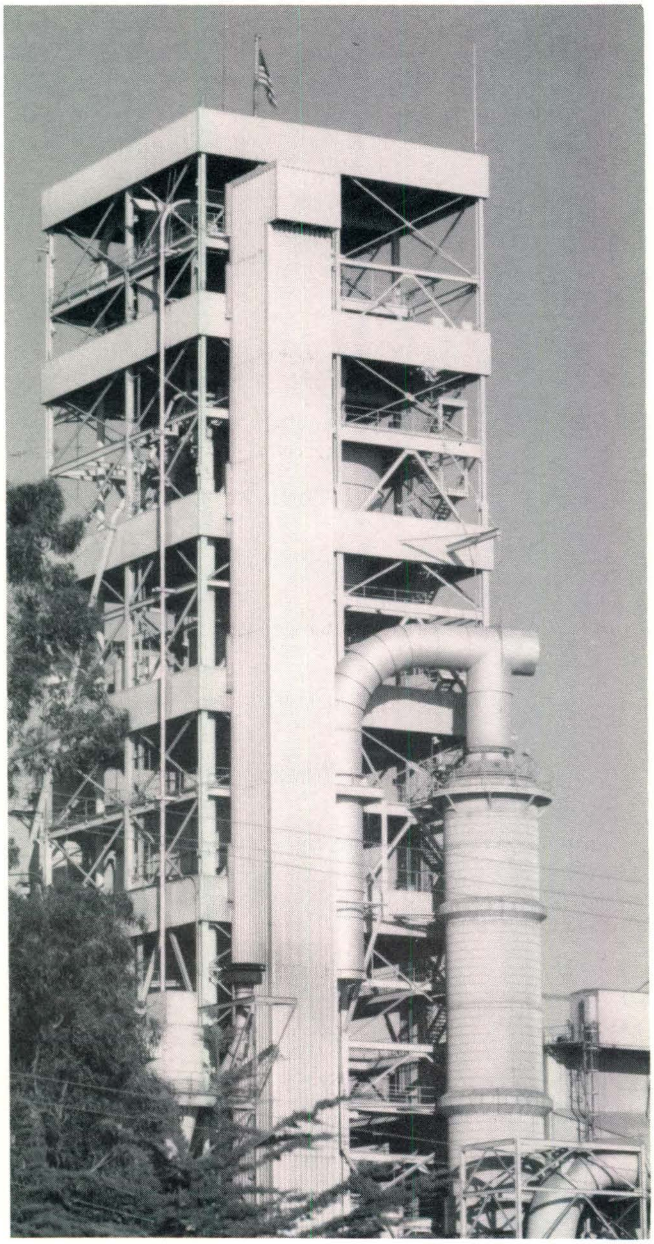
RAW MATERIALS PROCESSING

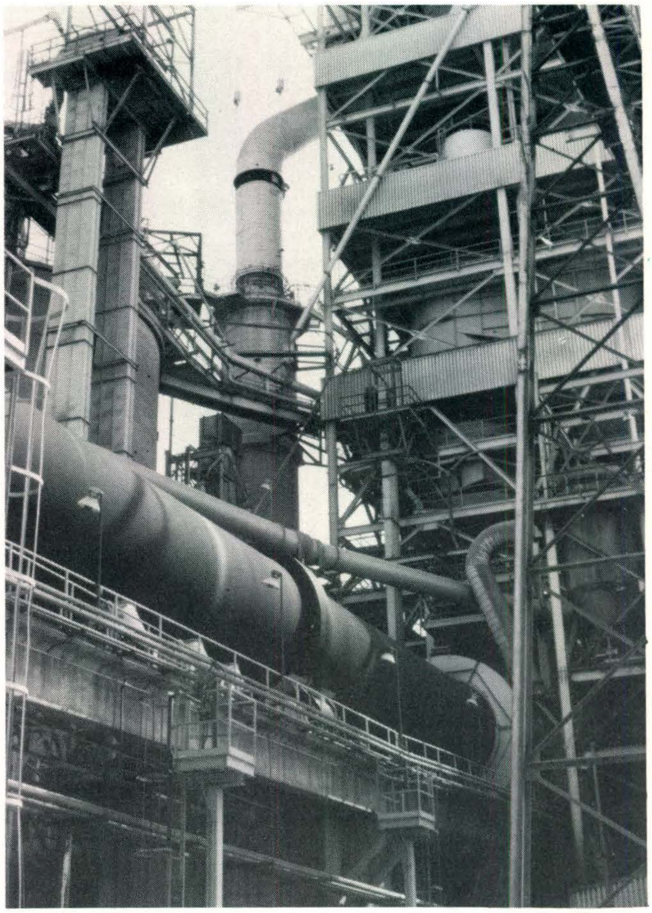
Raw materials are proportioned by chemical analyses, blended, and conveyed into an enormous roller mill (Photo 9). The roller mill dries the ore, crushes it further, and classifies it by size in one continuous operation. The ore is dried by utilizing hot exhaust gas from the kiln. Production capacity of the roller mill is about 205 tons an hour. The finely ground ore or "raw meal" is separated out by the main precipitator and conveyed into two large homogenizing silos (Photo 2). The main precipitator separates the meal from the gas stream and allows the clean gases to be vented at the main stack.

The homogenizing silos keep the raw material suspended in turbulent air so that it remains thoroughly blended. When the blend meets computer-monitored quality specifications, it is sent to the top of the 245-foot-tall preheater tower to be preconditioned for the kiln (Photo 10) (Polysius Corporation, 1981).

By utilizing a preheating process to condition the ore, the Davenport plant efficiently utilizes kiln heat that would otherwise be wasted. The kiln system is equipped with a bypass system to lower

* X-ray fluorescence spectroscopy precisely analyzes the chemical content of complex substances. With this type of laboratory analysis the characteristic X-ray spectrum of a substance is produced by using X-rays of short wavelength to induce the substance to emit X-rays of longer wavelength.





▲ Photo 11. Preheated meal from the flash calciner (within the preheater tower on the right) is fed into the rotating kiln and travels down the kiln to the left. As the heat increases, carbon dioxide and other gases are driven out of the raw material and chemical changes take place.

◀ Photo 10. Preheater tower (large rectangular building) is 245 feet high. By-pass precipitator is in the columnar structure on the right (Figure 3). The kiln feed is conveyed by an airlift system from the homogenizing silos to the top of the preheater tower. The coal-fired flash-calciner within the preheater tower rapidly transfers heat from hot gases to the raw meal, heating it from 100 degrees Fahrenheit to 1,600 degrees Fahrenheit in about 20 seconds. The flash calciner uses 60 percent of the fuel consumed at the plant.

the alkali content of the clinker (high alkali content is injurious to concrete). In addition to using kiln heat, the preheater tower incorporates a coal-fired flash calciner that rapidly heats the raw meal from 100 degrees Fahrenheit to 1,600 degrees Fahrenheit in just 20 seconds. The flash calciner uses 60 percent of the total energy consumed at the plant.

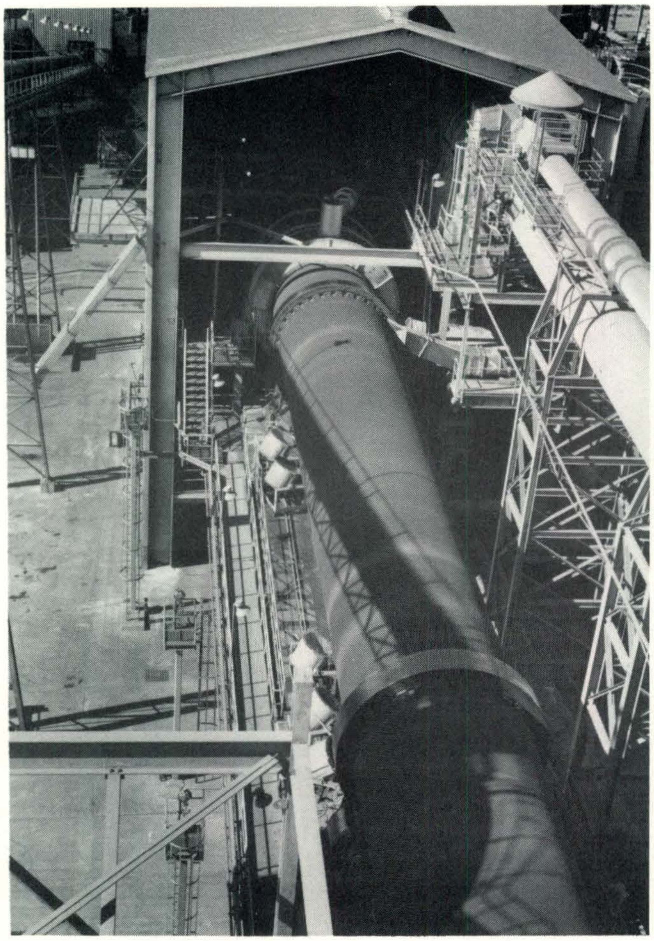
INTO THE KILN

After the blended raw meal, called "kiln feed," is preheated in the flash calciner it is fed into the kiln and heated to 2,700 degrees Fahrenheit within about 20 minutes (Photos 11, 12, and 13). As the kiln feed is heated, it becomes incandescent and changes from purple to violet and finally to orange when it forms new compounds and fuses into clinker.

Powdered coal is continuously fed into the kiln burner to produce the extreme heat needed to make clinker. A continuously-operating mill pulverizes the coal for rapid combustion in the flash calciner.

In most modern cement plants the raw materials are fed into a long rotary kiln. Some are as long as 700 feet. In such long kilns it can take up to four hours for the meal to gradually work its way down to the burning end and emerge as clinker. Kiln heat is wasted.

At the Davenport plant the kiln is only 185 feet long and the travel time for the meal through the kiln takes about 20 minutes. The heat produced by the flash calciner and kiln is captured in a closed-circuit circulation system to minimize heat loss, improve combustion, and conserve fuel (Figure 3).



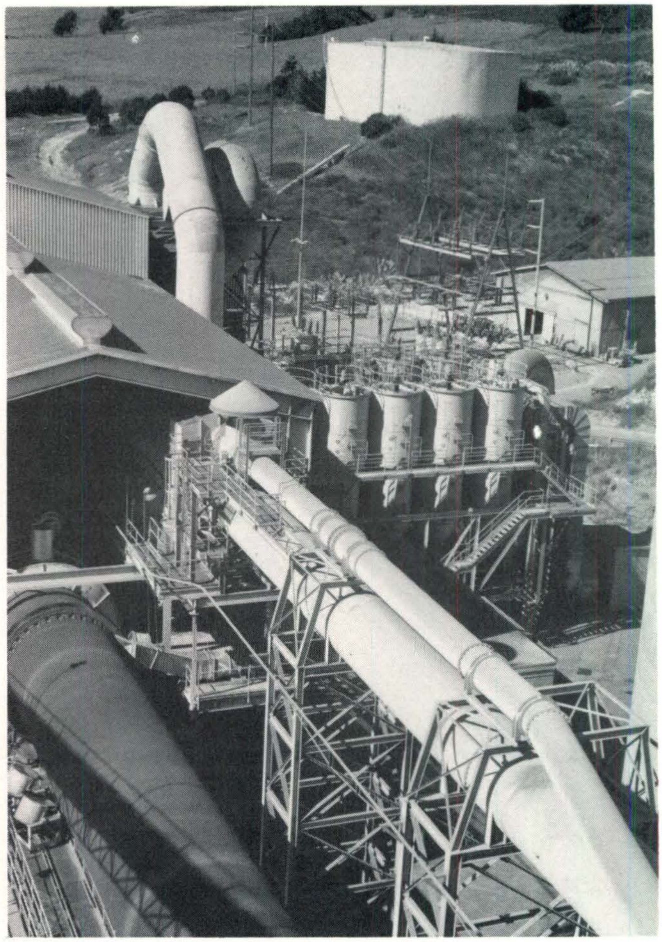


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Photo 12. View of the rotary kiln from the preheater tower. The kiln is 185 feet long, 13 feet in diameter, and rotates about 2½ times a minute on giant roller bearings. Once the preheated meal is fed into the kiln it takes about 20 minutes for it to move down the kiln and be transformed into clinker. The meal moves through the kiln (from the right of photo to top center) and enters the burner building (background) where it is heated to 2,700 degrees Fahrenheit — more than one-fourth the temperature on the surface of the sun.

▲

Photo 13. View of the kiln from the preheater tower. Hot clinker drops from the kiln onto moving grates within the burner building. The row of columnar cylinders to the right of the building are gravel bed filters that cleanse hot exhaust air from the clinker. The hot air return pipes from the clinker cooler are above and to the right of the kiln.

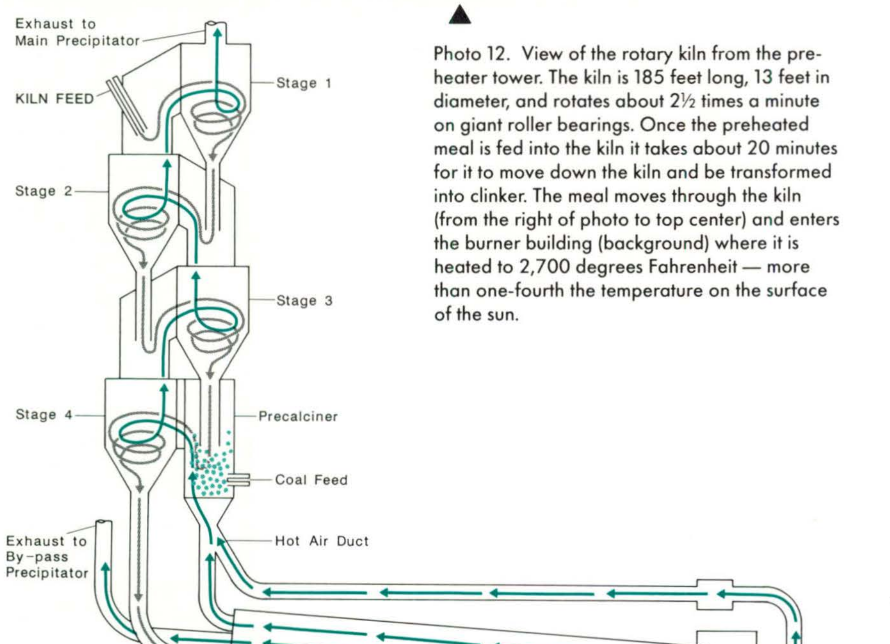

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Figure 3. Cross-sectional schematic view of the burning process and gas circuit for making portland cement at the Davenport plant. The blended raw materials are preheated as they descend through a rising flow of hot exhaust from the kiln and cooler. A complex arrangement of funnels or cyclones suspends the raw materials long enough to become preheated. The precalciner, also called flash calciner, is a furnace near the base of the preheater tower where coal is introduced and burned, driving off carbon dioxide in the raw materials. The remaining material, called "kiln feed," is heated to nearly 1,600 degrees Fahrenheit within 20 seconds. The kiln feed is then processed through the rotary kiln and travels toward the right in the diagram. As the materials reach the base of the kiln, they are heated to nearly 2,700 degrees Fahrenheit, undergo chemical transformation, and turn into clinker. *Adapted from Lonestar, 1981.*

Kiln exhaust is divided into two separate gas streams. About 25 percent of the kiln exhaust gases enter into the bypass system which consists of the mixing chamber, cooling towers, and electrostatic precipitator that enables the alkali in the kiln gases to be removed with the kiln dust. Because alkalies are harmful to concrete, this procedure provides reliable quality control of the finished cement. The remaining 75 percent of the kiln gases enters the flash calciner to preheat the combustion air and kiln feed.

As the clinker emerges from the kiln, it drops onto moving perforated grates where it is cooled to 250 degrees Fahrenheit by air forced through it. As the air cools the clinker, it also captures the heat for use in the kiln, the precalciner, and to dry the coal. The excess heated air is recycled back to the clinker cooler. It is cooled with the heat exchange fans and cleaned in the gravel bed filter.

FINISH MILLS

When the clinker is cooled, it is conveyed with a small amount of added gypsum (to control setting time) to the finish mills for final grinding. The finish mills are large rotating cylinders containing thousands of pounds of steel balls for grinding the clinker and gypsum into extreme fineness (Photo 14). The tumbling action of the mills reduces the clinker and gypsum to powder that will pass through a sieve containing 105,000 openings per square inch. The finished soft gray cement is much finer than flour or face powder.

Photo 14. A 39-foot-long, 12-foot-diameter rotary finish grinding mill. Gypsum is added to the clinker, then fed into the finish mills, where the tumbling action of tons of steel balls pulverizes the cement into a soft gray powder that is finer than flour.

Finished cement is conveyed into storage silos by a pneumatic pump. When needed, the portland cement can then be bulk loaded onto railroad hopper cars at the plant, bulk trucks, or packaged into paper sacks by plant personnel using automated machines (Photo 15).

◀ Photo 15. After the finish mill grinds the cement to powder it is conveyed to these storage silos. As needed, the cement is placed into bulk trucks (shown in photo), into handy 94 pound sacks, or into railroad cars. Most of the cement from the plant is shipped by bulk truck for customer convenience.

ENVIRONMENTAL ASPECTS

Reclamation

Reclamation plans for both the Bonny Doon limestone quarry and the Bonny Doon shale quarry have been approved by the Santa Cruz County Planning Department. Top soil from both quarries has been stockpiled and will be replaced during the reclamation process. Native vegetation will then be planted. Reclamation activities are ongoing at the Bonny Doon shale quarry. However, because more extensive mining operations are required to quarry the indurated meta-limestone at the Bonny Doon limestone quarry, reclamation procedures will commence upon completion of the extraction process.

Air Quality

The Davenport plant is located on the environmentally sensitive central California coast and is subject to stringent air pollution standards. In the 1970s when plans were being developed for the extensive remodeling, one of the most important objectives was to use modern technology to meet and exceed governmental air quality standards. Because the manufacturing process for high-quality cement normally produces significant amounts of air emittants, much effort was expended to ensure that the refurbished plant would not degrade the ambient air quality in the area.

The most troublesome air pollutants generated by the cement manufacturing process are emissions of (1) sulfur dioxide (SO_2), (2) nitrogen oxides (NO_X), and (3) particulates. Innovative solutions were engineered and implemented at the plant to avoid these emission problems:

(1) An alkaline slurry injection system at the plant is utilized to effectively control sulfur dioxide emissions. This system is the only one being used in the cement industry.
(2) Nitrogen oxide emissions at the plant are among the lowest in the country.
(3) To control particulate emissions from the main stack, an electrostatic precipitator was installed into the emission control system and operates at 99.995 percent efficiency. Air quality in the vicinity of the plant is continuously monitored. Instruments detect particulate matter as small as 10 microns in diameter (Lonestar, 1981; Polysius Corporation, 1981).

SUMMARY

Since 1906 high-quality cement produced at the Davenport plant has been used in many major construction projects in the primary market area throughout northern and central California. The growth of the California economy is directly tied to the availability of high-quality cement and related concrete products.

ACKNOWLEDGMENTS

I would like to thank Peter H. Cotter, Christopher Crouch, and Albert J. Cornibe, Jr. of RMC Lonestar who patiently explained the mining and manufacturing operations, made many helpful suggestions during manuscript review, and provided most of the photos and figures.

REFERENCES

Bowen, Oliver E. Jr., 1957, Cement *in* Wright, Lauren A., editor, Mineral Commodities of California: California Division of Mines and Geology Bulletin 176, p. 113-120.

Fitch, A.A., 1931, Geology of the Ben Lomond Mountain: University of California, Publications in Geological Sciences, Bulletin, v. 21, no. 1, p. 1-13.

Gudde, Erwin G., 1969, California place names, Third Edition: University of California Press, p. 84.

Jennings, Charles W. and Burnett, John L., 1968, San Francisco sheet, geologic map of California: California Division of Mines and Geology, scale 1:250,000.

Lonestar, 1981, The treasure of Santa Cruz: Lone Star Industries, Inc., Greenwich, Connecticut, 34 p.

Polysius Corporation, 1981, Lonestar Santa Cruz plant: F.L. Smidth and Company, Cresskill, New Jersey, 8 p.

Trask, Parker D., 1926, Geology of the Point Sur quadrangle: University of California, Publications in Geological Sciences, Bulletin, v. 16, no. 6, p. 119-186.

Announcements

28th International Geological Congress

The Twenty-Eighth International Geological Congress (IGC) will be held in Washington, D.C. from July 9-19, 1989. Over 6,000 earth scientists from more than 100 countries will attend the Congress. The meeting is sponsored by the International Union of Geological Sciences and will be hosted by the U.S. Geological Survey and the U.S. National Academy of Sciences.

IGC, which is convened every three to five years, provides a forum for geoscientists to present new findings and exchange ideas on topics ranging from research on earthquakes and volcanoes to the recovery of oil and water.

IGC was held in 1984 in Moscow and previously in 1980 in Paris, the site of the first IGC in 1878. IGC last met in the United States in 1933.

Two major colloquia will highlight the twentieth anniversary of the Apollo 11 lunar landing and provide an assessment of world natural resources. Other symposia will focus on: (1) Influence of extraterrestrial impact phenomena on the course of geologic history, including the death of the dinosaurs and other orders; (2) New tools and frontiers in the exploration for oil and gas; (3) Energy and mineral resources of the circum-Pacific region; (4) Advances in earthquake prediction; (5) Hydrogeology and radioactive waste management; and (6) Rate and frequency of volcanic eruptions.

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Catalog of Well Samples

The fifth edition of the California Well Sample Repository Catalog of Well Samples is now available for $3.00. The new catalog contains listings for nearly 4,000 wells throughout California.

Obtain copies from: California Well Sample Repository, California State University, Bakersfield, 9001 Stockdale Highway, Bakersfield, CA 93311-1099. For information call Larry Knauer, curator, at (805) 664-2324.

Alfred Oswald Woodford, circa 1910, as an undergraduate student at Pomona College.

Geologists of California Series

ALFRED OSWALD WOODFORD

By

DOROTHY LALONDE STOUT, Geologist
Division of Mathematics, Science, and Engineering
Cypress College, Cypress, California

Alfred Oswald Woodford significantly advanced the science of geology in California in the early 1900s and was instrumental in the training of many geologists. Woodford founded one of the first college geology programs in southern California. Woodford was born on February 27, 1890 in Upland, California and preparations are being made to celebrate his 100th birthday next year.

FAMILY BACKGROUND

Woodford's father, Butler A. Woodford, arrived in southern California in 1888 and settled in the Ontario area. He soon was involved in the citrus industry as manager of the Southern California Fruit Exchange, the Sunkist Cooperative. Upland, formerly known as North Ontario, was named by Butler A. Woodford.

Woodford's mother's family, the Harwoods, were early developers in the area. The Harwoods generously contributed to the development of Pomona College, a Congregational denomination school that was established in 1888. Frank Harwood, Woodford's uncle, was chairman of Pomona College Board of Trustees during part of the time Alfred Woodford taught at the school.

EDUCATION AND EARLY CAREER

Woodford's early schooling was in the classics. At Pomona College, he was influenced by Dr. James Lyman, professor of chemistry, whose historical approach to science captured Woodford's imagination. At a time when Pomona Valley was largely a citrus grove area, Lyman and the faculty of the Biology Department recognized the importance of teaching agricultural chemistry at Pomona College. Many Pomona College students were from families involved in farming and one goal of college training was to give these students practical knowledge.

Upon completing his degree at Pomona College in 1913, Woodford was employed in the family business. His interest in soils led him to seek an advanced degree in soil science at the University of California, Berkeley in 1915. To obtain a better understanding of the origin of soils, Woodford enrolled in optical mineralogy taught by E.F. Davis, a geology instructor who was completing his doctorate in geology at the University of California, Berkeley.

After studying optical mineralogy, Woodford changed his major to geology. His course work in geology was taught by eminent geoscientists at the University of California, Berkeley. Andrew C. Lawson taught general geology; George Louderback taught mineralogy, and John C. Merriam taught historical geology.

During the next few years Woodford divided his time between graduate work and teaching. He was appointed to the Pomona College faculty and began teaching mineralogy and soil chemistry in February 1916 in the Chemistry Department in close association with Lyman.

When the United States entered World War I in 1917, steelmakers needed chrome and manganese. Professor Louderback, sponsored by the U.S. Bureau of Mines, organized a team of Berkeley graduate students (Roy Morse, Nicholas L. Taliaferro, E. Fred Davis, and Woodford) to examine prospects in the Franciscan Complex of the Coast Ranges north of Berkeley. Again in summer 1918 Woodford was involved in mineral resource exploration.

After the war, Pomona College deemphasized agriculture and the soil chemistry course was dropped. In 1919 Woodford began to teach geology classes at Pomona College. There were nine students in his first class; two became geologists.

Members of a geology seminar group conducted by Andrew C. Lawson at the University of California, Berkeley in 1917. Left to right, front row: John P. Buwalda, Francis E. Vaughan, Chester Stock, Andrew C. Lawson, E. Fred Davis, Frank S. Hudson, William S.W. Kew. Back row: C.L. Moody, J.C. Ray, Carl Lausen, Clifton W. Clark, Nicholas L. Taliaferro, Roy R. Morse. *From Vaughan, 1970.*

DISSERTATION

In 1921 Woodford took leave from his teaching position at Pomona College to complete his graduate work and doctoral dissertation at the University of California, Berkeley. His advisor, Professor Louderback, suggested that the geology of the Irvine Ranch property in Orange County would be a good project for his dissertation. Preliminary work had been done in mapping and describing the geology (San Onofre Breccia) for oil prospects by Roy Morse.

In May 1922 Woodford finished his studies at University of California, Berkeley, and graduated in 1923 with a Ph.D. His dissertation, *The San Onofre Breccia, Its Nature and Origin,* was published in 1925. It was considered a classic work. According to Woodford's theory, during the Miocene Epoch an extensive landmass existed offshore which was the provenance for sediments shed eastward to form the now exposed 40-mile-long San Onofre Breccia that occurs along the southeast coast of Los Angeles County. The wedge-shaped breccia mass was composed of clasts of glaucophane schist and related rocks from dust particle size to blocks 15 feet long. The breccia ranged from a maximum thickness of about 1,500 feet near shore on the west, thinning five to ten miles eastward and inland. The geologic concepts he proposed in his dissertation were innovative. He correlated the Catalina Schist on Catalina Island as a remnant of a former upraised landmass that provided the debris for the San Onofre Breccia in the Los Angeles basin (Woodford, 1925).

GEOLOGY DEPARTMENT

Woodford's enthusiasm and insight into the opportunities for applied earth sciences in southern California prompted him to establish a separate Geology Department at Pomona College in 1922. Woodford's father paid for the necessary geology equipment. In 1924 T.F. (Jerry) Harriss and Richard Short graduated and were presumably the first geology majors from Pomona College to become professional geologists.

Although Woodford felt inadequately trained in some geologic areas, such as geomorphology and paleontology, in the years that he taught the entire geology curriculum at Pomona College, his students were sufficiently well trained to be accepted as graduate students at prestigious universities.

Woodford worked as a one-man department with a few geology students graduating each year. The personalized attention he gave to the students, along with field trips and research projects, led to lifelong friendships. The record of this department indicates that an unusually high percentage of students matriculated to major institutions for graduate work and later made significant contributions in the geological sciences.

Numerous successful students through the years stand as a monument to Woodford's teaching methods and endeavors.

Members of a geology seminar conducted by Professor Andrew C. Lawson at the University of California, Berkeley in 1922. Left to right, front row: William F. Foshag, Tate McCarey, Andrew C. Lawson, Richard Nelson. Back row: Robert P. Miller, Marcus A. Hanna, Alfred O. Woodford, Parker D. Trask, Quay S. Diven, Jesse B. Leiser, Merle C. Israelsky. *From Vaughan, 1970.*

Members of The Rift Club on a field trip to the Elsinore area, Riverside County, February 1926. In 1926 William Morris Davis, geomorphologist from Harvard University, visited California. When he lectured at Claremont College, Woodford and Davis became friends. Davis organized the Rift Club of Southern California which met informally several times a year to examine the location of faults for study and discussion. Left to right: Ranger (name unknown), Mason L. Hill, William Morris Davis, A.O. Woodford (in knickers). Others unidentified.

Rollin Eckis, one of Woodford's students, completed graduate work at the California Institute of Technology and became Executive Chairman of the Board of Atlantic-Richfield Company. Eckis stated that Woodford "had a unique ability to inspire interest and imagination in students. . . . he had a flare for the dramatic. . . . he had time for anybody that would make a good geologist."

Charles Anderson graduated from Pomona College in 1924 and went to graduate school at the University of California, Berkeley. He became a professor of geology at the University of California, Berkeley, and later was Chief Geologist of the United States Geological Survey. Other successful geologists who were students of Woodford were Dana Russell, a 1927 graduate of Pomona College; Rod Cross and Stanton Hill, 1933; the Shelton brothers — John, 1935; Hal, 1938; and Richard, 1941; Warren Addicott, Wayne and Willis Burnham, and Ivan Colburn, 1951; and Alex Baird, 1954.

Another of Woodford's former students, Roger Revelle, became director of Scripps Institute of Oceanography. Revelle, like many of Woodford's former students, shared his discoveries and successes with Woodford over the years.

Woodford's teaching methods consisted of examining objects to determine how the parts made up the whole — a method used by Louis Agassiz, a glaciologist and popular Harvard professor in the mid-1800s. In this method a student was required to work out a problem by trial and error.

Members of The Rift Club in Cucamonga Canyon, San Bernardino County, September 1926. Left to right: F.P. Vickery (University of California, Los Angeles), Rollin Eckis (in white shirt), profile of W.S.W. Kew, Mr. Surr (with pipe), Levi Noble (front center), John May (Pomona College student, wearing bow tie), Mr. Peters, Kenneth Garner, and A.O. Woodford (in knickers, holding collapsible camera).

PEER RECOGNITION

In 1955 the National Association of Geology Teachers highest honor, the Neil A. Miner Award, was presented to Woodford. In his acceptance speech during the Geological Society of America Annual Meeting in New Orleans, he stated his reason for choosing geology as his profession: "We are geologists because we love beautiful mineral specimens or fine fossils or magnificent mountains. I myself turned from soil science to petrography so that I could spend my life looking at interference colors of beautiful minerals . . ." (Woodford, 1955).

Woodford was generous with his time when geologists requested him to review their manuscripts. He was active in the Cordilleran Section of the Geological Society of America and served as secretary of the section from 1933 to 1936. His students, following his example, became very active in professional geological organizations.

Woodford's writing ranged from articles in periodicals to textbooks to the philosophy of geology. He collaborated in 1951 with James Gilluly of University of California, Los Angeles, and Aaron Waters of Stanford University in writing *Principles of Geology*, which became a standard text in the 1950s and 1960s for beginning geology courses.

Students on field trip to Rose Canyon, San Diego County, conducted by Professor A.O. Woodford in 1930; view toward the east. Left to right: Stewart Hagestad, Arthur Colley, Mr. Squires, Richard Bramkemp, Mr. Stroud, Rollin Eckis, Roger Revelle, Edward Dew.

RETIREMENT ACTIVITIES

In 1955 after three and a half decades of teaching geology, Woodford retired from Pomona College and was appointed Emeritus Professor. He continued to be active in teaching, research, and writing. In 1957 he became president of the Cordilleran Section of Geological Society of America. He was president of the National Association of Geology Teachers — Far Western Section in 1959, and president of the National Association of Geology Teachers in 1962.

Woodford, along with some of his former students, was involved in 1963 in commemorating the seventy-fifth anniversary of the Geological Society of America by writing *The Fabric of Geology*. In 1965 he published *Historical Geology*. In this volume he honored his historical geology teacher, John C. Merriam, University of California, Berkeley, by saying, "I am following the practice of the great teacher from whom I first learned about geologic history . . . whose lectures at the University of California I heard in 1915. I am still trying to use Merriam's method . . ." (Woodford, 1965).

Woodford's interest in the historic aspects of science first learned from Lyman, his chemistry professor, are reflected in the Woodford Room in the Mudd Science Library at Pomona College. This room contains rare books tracing the evolution of geology as a science. This extensive personal collection grew with acquisition of the Dr. James Perrin Smith (Stanford University) collection, duplicates from the Agricultural Library at University of California, Berkeley, the Harold Fairbanks collection, and gifts of Donald McIntyre and Stanton Hill, Pomona College alumni.

Woodford's influence in the geosciences has been felt throughout California and the world. Today, Woodford lives in Claremont and is visited often by his two daughters, Betsey and Marjorie, and grandchildren and great grandchildren, his former students, and his friends. Each year his birthday is marked by the Woodford-Eckis Lecture Series when alumni and friends meet to celebrate Woody's birthday. In 1988, Harrison Schmidt, astronaut and former Senator, was the invited speaker; this year Robert Sharp, California Institute of Technology, was the featured speaker for the 99th birthday celebration.

ACKNOWLEDGMENTS

Appreciation is extended to the staff and alumni of Pomona College who have been generous with their time and materials, especially Ivan Colburn, Rollin Eckis, Mason Hill, Jean McKay, and A.O. Woodford, and Betsey Coffman, Woodford's daughter.

REFERENCES

Bates, C.C., Gaskell, T.G., and Rice, R.B., 1982, Geophysics in the affairs of man: Pergamon Press, Oxford, 492 p.

Davis, Gregory A. 1980, Geological sciences at the University of Southern California (Appendix): Prepared for Board of Trustees Meeting.

Davis, William Morris, 1926, Letter to A.O. Woodford, March 2.

Jackson, Kathy, 1983, History of the geosciences: University of California, Los Angeles Newsletter, p. 9-16.

Revelle, Roger, 1931, Letter to A.O. Woodford, November 2.

Schoellhamer, J.E., Vedder, J.G., Yerkes, R.F., and Kinney, D., 1981, Geology of the northern Santa Ana Mountains, California: U.S. Geological Survey Professional Paper 420-D.

Steller-Stout, Dorothy L. 1983, Oral history interview with Mason L. Hill, October 25.

Steller-Stout, Dorothy L., 1984a, Oral history interview with A.O. Woodford, January 13.

Steller-Stout, Dorothy L. 1984b, Oral history interview with Rollin Eckis, August 15.

Vaughan, Francis E., 1970, Andrew C. Lawson, scientist, teacher and philosopher: Arthur H. Clark Company.

Woodford, A.O., 1925, The San Onofre Breccia — its nature and origin: University of California, Department of Geological Sciences Bulletin, v. 15, no. 7, p. 159-280.

Woodford, A.O., 1955, National Association of Geology Teachers Award: Journal of Geological Education.

Woodford, A.O., 1965, Historical geology: W.H. Freeman, San Francisco, 512 p.

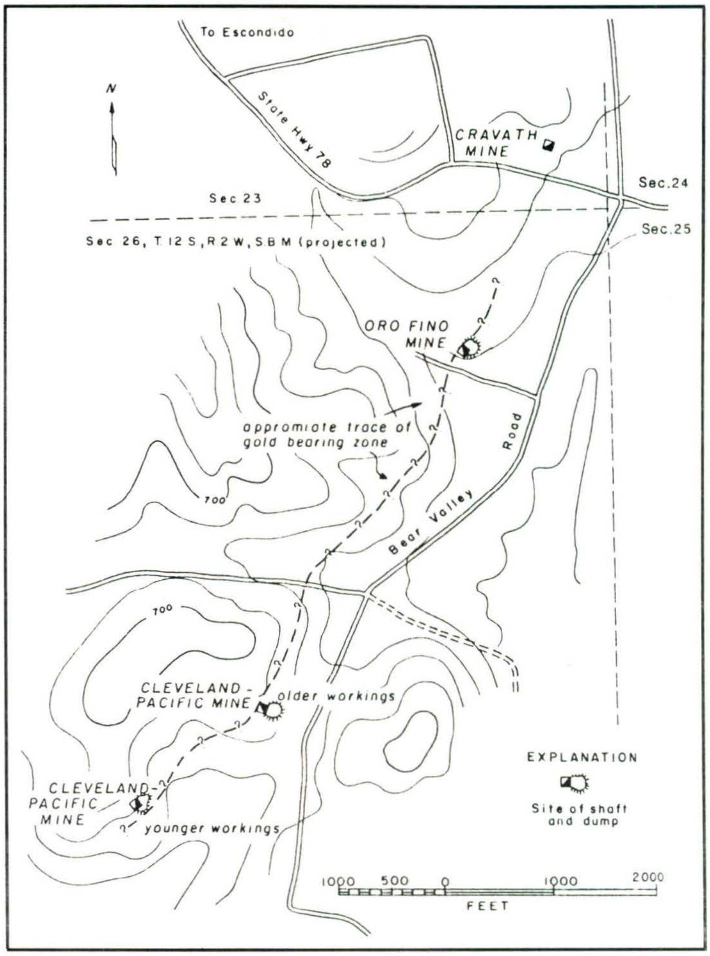
In 1954, to commemorate the first annual Geological Society of America meeting held on the west coast (Los Angeles), the California Division of Mines and Geology published Bulletin 170, *Geology of southern California*. The contents of this volume summarized, up to this point in time, the growing knowledge of southern California geology. The bulletin was edited by Richard Jahns of the California Institute of Technology and included chapters written by Woodford's former students at Pomona College including: Wayne Burnham, 1951 (Structure and minerals at Crestmore); Paul Dudley, 1925 (Signal Hill oil field); Cliffton H. Gray, Jr., 1953 and A.O. Woodford (Elsinore fault); Mason L. Hill, 1926 (Faulting in southern California); Thane McCulloh, 1949 (Igneous and metamorphic petrology in the Mojave region); Richard Merriam, 1934 (Peninsular Range bedrock); Manley Natland, 1928 (Foraminifera); Jack Schoellhamer, 1942, Jack Vedder, 1948, and Robert Yerkes, 1950 (Los Angeles basin); and John Shelton, 1935 (Miocene volcanism in southern California). This volume (now out of print) was one more example of the enthusiastic cooperation among a generation of geologists trained by Woodford.

Gold Mines of Escondido

San Diego County

By

FRANK LOREY, Historian
Escondido, California



Escondido mining district, Peninsular Ranges, San Diego County, California, showing sites of Oro Fino, Cleveland-Pacific (Escondido), and Cravath mines. *From Weber, Harold F. Jr., 1963.*

INTRODUCTION

In Spanish "escondido" means hidden, and hidden just southeast of the town of Escondido was one ore deposit which produced enough gold and silver to rank the Escondido gold mining district as the third largest in San Diego County. Over $160,000 worth of gold was taken out of a single quartz vein which ranged in width from two inches to six feet and could be followed for a distance of three quarters of a mile in length. This vein supported two productive gold mines — the Oro Fino and the Escondido (Cleveland-Pacific) mines. Additional claims were located near Escondido.

The Escondido district is in the Peninsular Ranges of western San Diego County about 25 miles north of San Diego and 20 miles southeast of Oceanside. It was the scene of mining activity from before 1860 until the mid-1920s. The dollar figure recorded for the district production — $60,000 — is not impressive by current standards because the average price for gold at the time was $20 per ounce and $5 per ounce for silver. At today's prices, the production totals for the mines would be close to $3 million.

HISTORY OF MINING

Geologic Setting

The Escondido district is underlain by granodiorite, diorite, and gabbro. The hills just west of the intersection of San Pasqual Road (State Highway 78) and Bear Valley Parkway are the site of a northeast trending, quartz-bearing shear zone in the local granite rocks. The quartz contains free gold, some silver, and abundant pyrite.

Oro Fino Mine

The oldest mine in the Escondido district was the Oro Fino (Spanish meaning fine gold). It was first called the El Diablo mine, after the Spanish land grant, Rincon del Diablo, where it was discovered. In the earliest days this mine was worked by Mexicans, using Indian labor. The Mexicans, however, abandoned it before 1860. Records of 1868 give little detail of the early mining operations, which apparently were surface diggings. The ore was processed in a crude mill known as an arrastre.

In 1886 the Escondido Land and Township Company assayed the vein of gold-bearing quartz and reserved the claims for possible later use. By 1894 a 40-foot deep shaft had been extended below the surface workings with tunnels following the vein. At that depth the quartz vein ranged from two to ten inches wide. A second shaft was sunk to 330 feet with over 1,000 feet of tunnels. A five-stamp mill was set up on the property to crush the ore.

The Oro Fino mine was the most productive mine in the Escondido district with a recorded production of 2,500 ounces of gold and 1,500 ounces of silver. The Stough family of Escondido operated the mine. The number of men working in the mine is unknown. The boom period of 1894 to 1901 ended with the shafts being blasted with dynamite to seal them off. Both shafts were subject to severe flooding problems, which may have led to their abandonment. The site is now a housing development and no trace remains of the Oro Fino mine.

Head frame at Cleveland-Pacific mine (formerly Escondido), circa 1897. *Photo from Division of Mines and Geology Archives.*

Tailings from the Escondido mine (later called Cleveland-Pacific mine), about 2 miles southeast of Escondido in San Diego County. Citrus and avocado orchards are now growing in this area. *Photo by Frank Lorey.*

Escondido Mine

The Escondido mine, which in later years became the best producer in the district, was located just a few hundred yards west of the Oro Fino mine. In the 1860s Americans worked the Escondido mine. Ore was processed at the arrastre of the Oro Fino mine. Early records show the value of ore in 1860 to be $50 per ton, with some ore containing up to 2½ ounces of gold per ton and up to 4 ounces of silver per ton.

In 1896 the Cleveland-Pacific Company became owners of the mine, and the name of the mine was changed to the Cleveland-Pacific. The company sank a 350-foot deep shaft and worked 500 feet of drifts (tunnels) following the ore vein. A five-stamp mill was set up on the property to crush the ore and two 10-foot cyanide tanks were used for leaching the ore. Much of the gold recovered by the Cleveland-Pacific Company was from ore dumps left by early miners. The ore was crushed to a finer degree and then treated with cyanide to concentrate the gold.

In the later workings, the ore contained one quarter to one half ounce of gold per ton and one quarter ounce of silver per ton. The high content of pyrite in the rock made ore processing difficult.

The mine was idle from 1911 until 1924, when B.F. Brough and Associates of Toledo, Ohio acquired the mine. This company sank another shaft to 160 feet, with over 450 feet of tunnels running along the vein. The mine produced a total of 4,000 ounces of gold and 3,500 ounces of silver, for a total production value of $100,000 at that time. The mine was closed again in 1926.

The Escondido mine today is nothing more than two piles of tailings. The mill site and mined area are now covered by citrus and avocado groves.

Cravath Mine

The most easterly mine in the Escondido district was the Cravath mine. This mine consisted of a 100-foot deep shaft with a short tunnel leading to the vein. Very little work was done on the mine; no production was ever recorded, and no mill was set up on the property which indicates the quartz vein was most likely barren at this point. Homes now cover the site of this mine, and no trace remains of it.

Other Mines

In the 1880s and 1890s the Geneva Mining and Milling Company sank numerous shafts in the area on various claims. This company encountered only two quartz ore bodies which became the Jolly Boy mine and the Mountain mine. The zone of gold-bearing ore was quite narrow; both mines were unprofitable. Other shafts in the area had names such as Coyote, Able, Crescent, Golden Crescent, and Redrock. A few claims were prospected about six miles northeast of Escondido, but they were never serious mining efforts.

SUMMARY

Escondido had its place in gold mining history, but the value of the land for agricultural and residential uses now greatly surpasses all the gold and silver found there. Today all that remains of the mines are rock dumps and streets with golden names, such as El Dorado Drive and Del Oro Lane.

REFERENCES

Clark, William B., 1970, Gold districts of California: California Division of Mines and Geology, Bulletin 193, p. 171.

Escondido Historical Society, 1973, Escondido, a pictorial history, Escondido, California.

Gudde, Erwin G., 1975, California gold camps: University of California Press, Berkeley, California.

Merrill, Frederick J., 1914, San Diego County: XIV Report of the State Mineralogist, California Mining Bureau, p. 636-722.

Ryan, Frances, 1970, Early days in Escondido: Swadell Lithographers, Escondido, California.

Ryan, Frances and Ryan, Lewis, 1980, Escondido as it was, 1900-1950: Taylor Publishing Company, Escondido, California.

Storms, W. H., 1893, San Diego County: XI Report of the State Mineralogist, two years ending September 15, 1892, California Mining Bureau, p. 376-393.

Weber, F. Harold Jr., 1963, San Diego County: California Division of Mines and Geology County Report Number 3, p. 120-121.

BOOK REVIEWS

Books reviewed in this section are not available from DMG.

Death Valley Region

GEOLOGY OF THE DEATH VALLEY REGION, South Coast Geological Society, Field Trip Guidebook Number 16. Edited by Jennifer L. Gregory and E. Joan Baldwin. 1988. South Coast Geological Society, Inc., P.O. Box 10244, Santa Ana, CA 92711-0244. 429 p. $30.00 (California residents include 6% sales tax), soft cover.

This field guide, published in conjunction with the South Coast Geological Society 1989 meeting, consists of a road log and selected articles about Death Valley geology. The text describes points of interest in Death Valley from west to east and along the eastern flank of the valley from north to south.

The articles include both recent and "classic" studies and cover physical geology, stratigraphy, geomorphology, structural geology, and mineral resources of the area. Bibliographies and an addendum — the 1928 Field Trip of the Rift Club — are also included.

Papers, such as those within this guidebook that are prepared for special conferences, present a valuable scientific handbook of ongoing research.

Death Valley. *Photo from DMG Photo File.*

Economic Geology

GEOLOGY AND MINERAL WEALTH OF THE OWENS VALLEY REGION, CALIFORNIA, South Coast Geological Society: Field Trip Guidebook Number 15. Edited by E.M. Gath, J.L. Gregory, J.R. Sheehan, E.J. Baldwin, and J.K. Hardy. South Coast Geological Society, Inc., P.O. Box 10244, Santa Ana, CA 92711-0244. 180 p. $20.00 (California residents include 6% sales tax), soft cover.

Every year thousands of visitors travel through Owens Valley along Highway 395 and enjoy the scenic geology. Papers in this guidebook present geologic and other information about areas of eastern Sierra Nevada and southeastern California including Inyo Mountains, Red Rock Canyon, Searles Lake, Panamint Valley, Padre Crowley Vista Point Overlook, Owens Lake, the formation and geologic structure of Owens Valley, the White Mountains, Coso Hot Springs, and Fossil Falls.

Photos, illustrations, and maps assist the reader in understanding the fascinating geology of this scenic area of California. This guidebook will be useful to earth science students, teachers, and professional geologists, as well as the general public.

Geologic Art

THE ART OF GEOLOGY. Geological Society of America Special Paper 225. Edited by Eldridge M. Moores and F. Micahel Wahl. 1988. Geological Society of America, Publication Sales, P.O. Box 9140, Boulder, CO 80301. 147 p. $37.50, hard cover.

Over 16,000 earth scientists belong to the Geological Society of America (GSA) which is dedicated to the promotion of geological sciences. This volume was published to celebrate the 100th anniversary of the society and to illustrate the beauty that geologists see in the course of their work.

The volume consists of 250 dramatic and beautiful photographs in color of 69 subjects. The photos were all taken by geologists while they were at work in the field. Photos in the book vary in scale from a microscopic view of about 0.1 millimeter across to a view of the surface of Mars that is several kilometers across. The brief explanatory text that accompanies each photo is designed for non-scientists.

Geologic Map

GEOLOGIC MAP OF ARIZONA. Map 26. By Stephen J. Reynolds. 1988. Arizona Geological Survey in cooperation with the U.S. Geological Survey, 845 North Park Avenue, #100, Tucson, AZ 85719. Scale 1:1,000,000. $5.00, plus $1.75 postage and handling for a folded map, or $2.75 for a rolled map.

Arizona Geological Survey has released a new geologic map of Arizona (scale 1:1,000,000). The map supersedes the 1:500,000-scale geologic map of Arizona which was published in 1969.

Printed in 30 colors, the map incorporates significant improvements based on detailed geologic mapping and new concepts. Most map changes are in the Basin and Range province and the Transition Zone where compilers had previously relied on reconnaissance mapping; numerous changes are also evident in the the Colorado Plateau province.

The map is printed on synthetic water-resistant paper that will make it durable for field use in varying weather conditions.

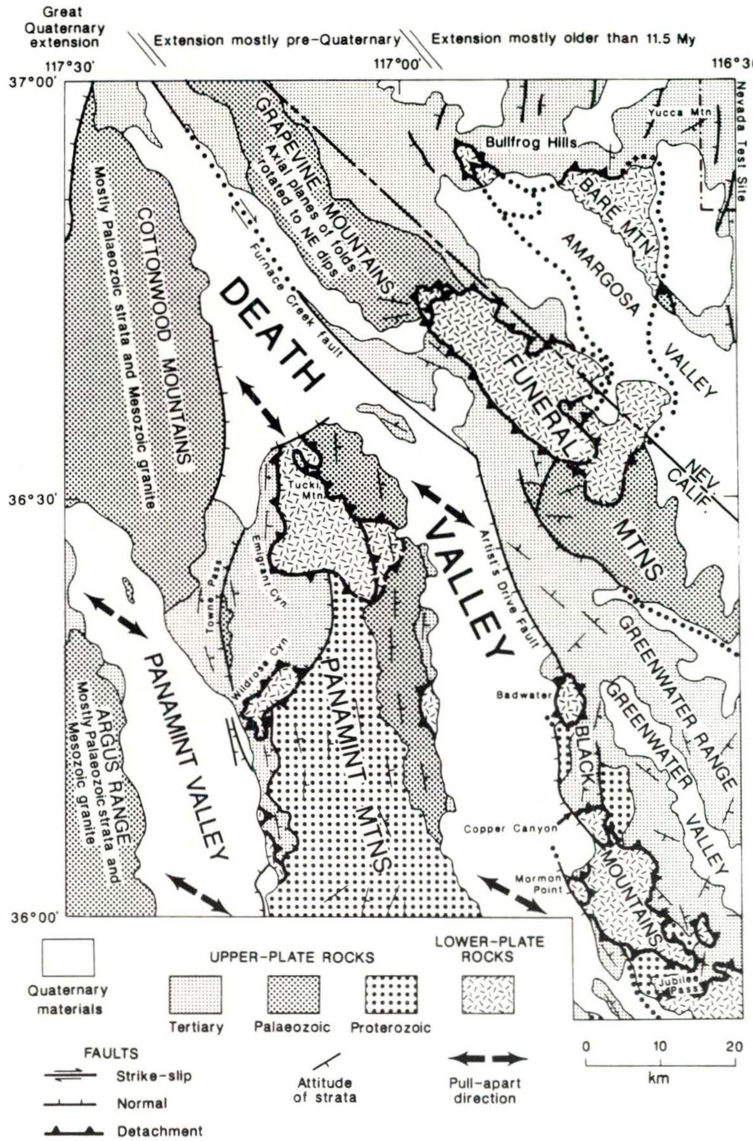
Structural Geology

CONTINENTAL EXTENSIONAL TECTONICS, Geological Society Special Publication No. 28. Edited by M.P. Coward, J.F. Dewey, and P.L. Hancock. 1987. Blackwell Scientific Publications, Inc., P.O. Box 50009, Palo Alto, CA 94303. 637 p. $115.00, hard cover.

Thirty nine of the papers given at a Conference on Continental Extension Tectonics held at the University of Durham, England, during April 1985 are included in this volume. The conference was cosponsored by the Geological Society of London and The Royal Society. The conference examined the geometry and mechanics of continental extension and basin development.

Extensional tectonics is important in understanding the development of northwestern Europe, North Sea deposits of oil and gas, the Basin and Range province in the western United States, southeastern Australia, Aegean Sea, Red Sea, and regions of Africa and Antarctica.

Several papers examine the mechanisms of mid- to lower-crustal extension and how it relates to the geothermal gradient and crustal thickness. Some papers describe the geometry of extensional faulting determined by earthquake seismology. Several papers describe how crustal extension affected the geology in some regions of California.



Tectonic map of the Death Valley region, southeastern California. Most normal faults are omitted. Note how extensional forces formed Panamint and Death valleys. This map is from a paper titled *Crustal extension in the Basin and Range Province, southwestern United States* by Warren Hamilton, U.S. Geological Survey, Denver, Colorado.

Thrust Faulting

THE LATE CRETACEOUS SAN JUAN THRUST SYSTEM, San Juan Islands, Washington. Geological Society of America Special Paper 221. By Mark T. Brandon, Darrel S. Cowan, and Joseph A. Vance. 1988. The Geological Society of America, Inc., Publication Sales, P.O. Box 9140, Boulder, CO 80301. 88 p. $19.00, soft cover.

This paper describes the stratigraphy and structure of the San Juan thrust system and explains the conclusions of recent geological mapping. The thrust system straddles the southeastern edge of the Wrangellia terrane on Vancouver Island. The conclusions rely heavily on abundant fossil isotopic dates, and on numerous analyses of volcanic and plutonic rocks.

Viticulture Map

VINEYARDS & WINERIES OF CALIFORNIA. By Donald Holtgrieve. 1989. Raven Maps and Images, 34 North Central Avenue, Medford, OR 97501. Scale 1:1,000,000; 42½ x 52½ inches. $35.00, paper; $60.00, laminated; plus $4.00 shipping and handling.

Over 85 percent of the wines produced in the United States come from California. This map indicates all bonded wineries in the state with their production levels. Special inserts cover the Napa-Sonoma area and California's 56 viticultural areas. An alphabetical list locates the wineries by county.

California is fortunate in having fertile soils, abundant water, and temperate climates to support a thriving agricultural industry. There are nearly 31 million acres of agricultural land in the state, including 9.5 million acres of irrigated cropland. Viticulture, the science of grape growing, is an expanding and increasingly important industry within the state. California wines and winegrowing technologies are exported worldwide.

This colored map is designed for wall display.

Pacific Crest Trail

THE PACIFIC CREST TRAIL. Volume 1: California. Fourth Edition. By Jeffrey P. Schaffer, Ben Schifrin, Thomas Winnett, and Ruby Jenkins. 1989. Wilderness Press, 2440 Bancroft Way, Berkeley, CA 94704. 475 p. $24.95, paperback.

Pacific Crest Trail stretches 2,550 miles from Mexico to Canada through California, Oregon, and Washington. The trail traverses national forests, wilderness areas, and national parks. It is near sea level at the Columbia River in Oregon and rises to 13,180 feet at Forester Pass in the Sierra Nevada. To walk the entire trail would take from five to six months.

Volume 1 covers 1,680 miles of the trail through California (Volume 2 covers Oregon and Washington). Eighteen sections in this book provide a description of various segments of the route and contain over 230 topographical map strips. Information is provided on natural history (geology, flora, and fauna), trail mileage, elevation, permits, alternative routes, safety measures, and cultural history.

Tuolumne Meadows. *Photo by Andrew C. Lawson, circa 1903.*

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Geology of Central England

GEOLOGY OF THE COUNTRY AROUND COALVILLE, Memoir for 1:50,000 geological sheet 155, England and Wales. By B.C. Worssam and R.A. Old. 1988. British Geological Survey. Available from HMSO Publications Centre, P.O. Box 276, London, England SW8 5DT.

Centrally situated in the Midlands, the district described in this Memoir is largely underlain by Triassic rocks, preserved within the Hinckley Basin. Seismic investigations indicate that the Triassic base lies more than 800 m deep in the deepest part of the basin. In the north-east the late Precambrian rocks of Charnwood Forest emerge through the Triassic cover to form hills rising to over 200 m. In the north, partly concealed by Triassic rocks, are parts of the Leicestershire and South Derbyshire coalfields and in the southwest, the north part of the Warwickshire Coalfield is exposed close to the Cambrian rocks near Atherstone.

The results of a geological survey on the scale of 6 inches equals 1 mile, carried out from 1963-1977 and supplemented by data from deep boreholes are presented here. Together with much coalfield information made available by British Coal, they enable a modern synthesis of the district's stratigraphy and geological structure to be made.

Glacial deposits cover a large part of the district, particularly the lower ground. Their emplacement and subsequent dissection by erosion have profoundly influenced present-day topography and drainage.

Although coal reserves within the district are limited, mineral working remains important and its prospects are examined in the chapter on economic geology. The Coal Measures of the South Derbyshire Coalfield include one of the largest accumulations of high-alumina refractory clays in the United Kingdom. The quarrying of igneous rocks as a source of aggregate has regional importance, and there are also extensive workings for brick clays and sand and gravel.

Physical Geology Lab Manual

EXERCISES IN PHYSICAL STRATIGRAPHY AND SEDIMENTOLOGY. By William J. Fritz and Johnnie N. Moore. 1988. John Wiley & Sons, 605 Third Avenue, NY 10158. 228 p. $22.35, soft cover.

A variety of practical exercises on physical stratigraphy and sedimentology are included in this laboratory manual. The manual was prepared to accompany *Basics of Physical Stratigraphy and Sedimentology* by the same authors and publisher (1988). It could, however, be used separately with limited rock and sediment collections. Organized into seven chapters, the manual covers library research and report writing, stratigraphic principles and correlation, texture and grain size analysis of sedimentary particles, sedimentary structures, rock descriptions and stratigraphic columns, fence diagrams, and paleofacies reconstructions. A bibliography and data collection forms conclude the manual.

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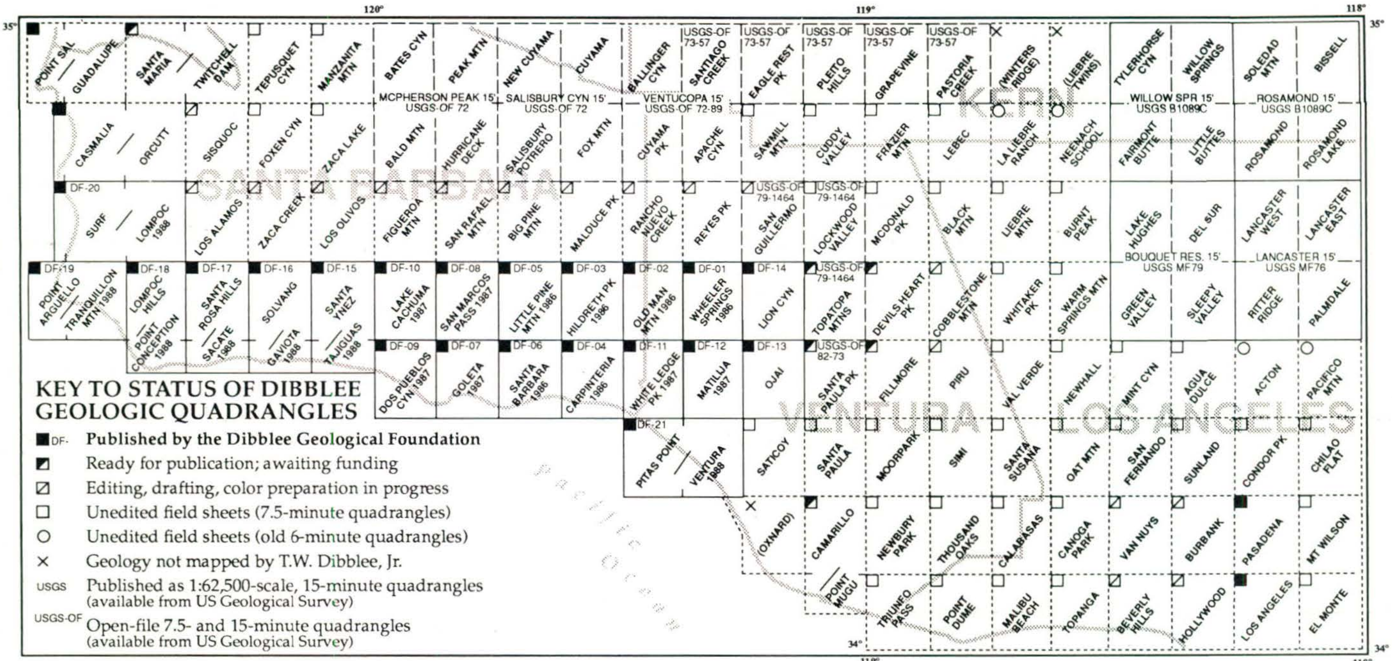

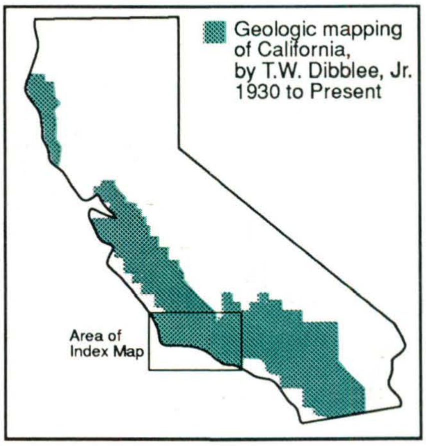

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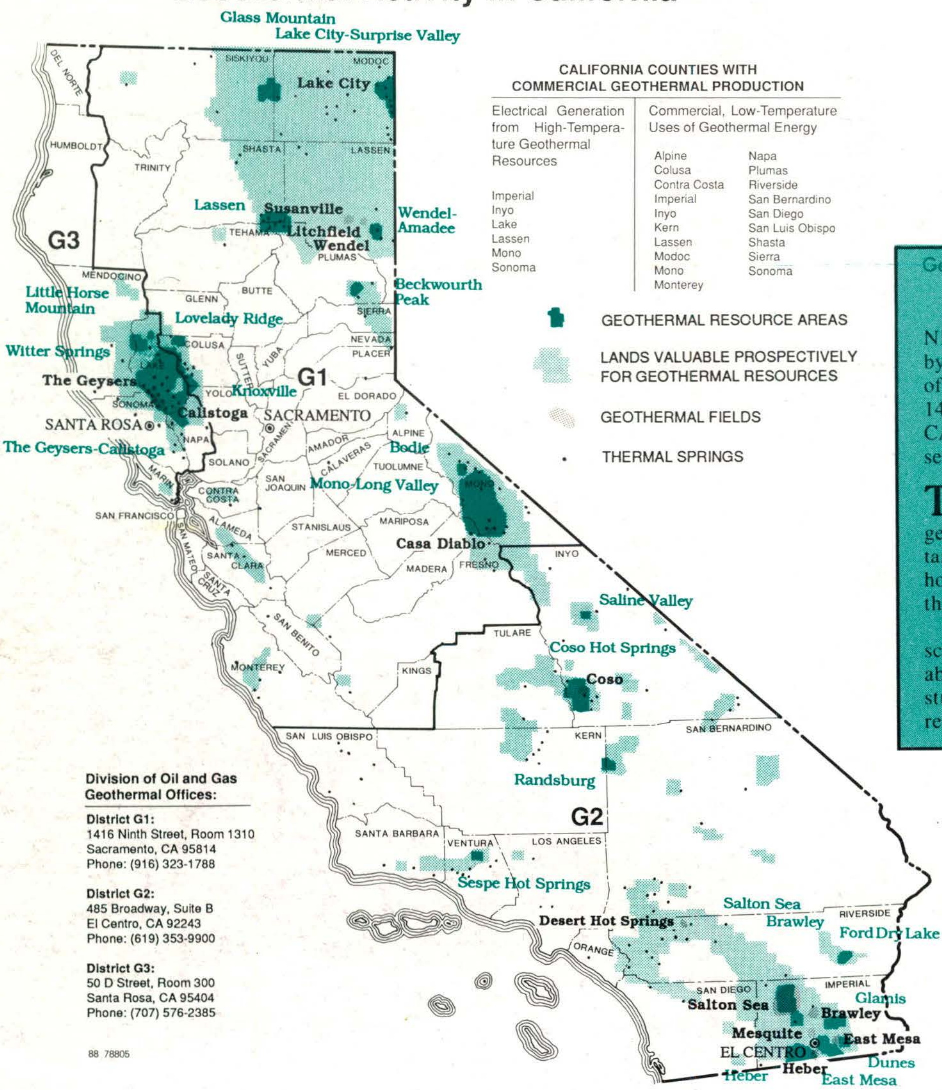
Geothermal Activity in California



Geothermal Energy

GEOTHERMAL ENERGY IN CALIFORNIA. Text by Susan F. Hodgson. Illustrations by Jim Spriggs. 1988. California Department of Conservation, Division of Oil and Gas, 1416 Ninth Street, Room 1310, Sacramento, CA 95814. 22 p. Individual and classroom sets are available free-of-charge. Soft cover.

This booklet provides an introduction to geothermal energy in California. The importance of geothermal energy, how it originates, how it is used, and locations in California that have geothermal energy are included.

The booklet is in a cartoon format and describes how a teenage brother and sister learn about geothermal energy. It is designed for students in fourth through ninth grades and readers who want a review of the subject.