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through a rotary screen. Coarse shells were crushed in rolls in closed circuit with the screen. Crushed shells were sold for poultry food.

Santa Clara Holding Company's quarry is in secs. 17 and 18, T. 7 S., R. 2 W., M.D. This is in the locality where Permanente Cement Company is now operating. The land is on the east slope of Black Mountain and is 3 to 4 miles west of Simla, a railroad point. It may be called a type locality for the Calera (Franciscan) limestone. When freed from chert and shale it made good lime for beet-sugar refining and was so used for many years by El Dorado Sugar Company and Alameda Sugar Company. Several small quarries were worked but the property had been idle many years up to 1934, when the company shipped some limestone from Simla.

The above refers to the shallower aspects of the limestone, and fuller details are given under Permanente.

San Jose Cement Company (which lapsed as a corporation as of March 4, 1936), was mentioned by Franke (30a) as owner of a deposit of limestone on 331 acres of land in secs. 4 and 5, T. 9 S., R. 1 E., and sec. 32, T. 8 S., R. 1 E., M.D.

This land is about 4 miles west of New Almaden and southeast of the Guadalupe mine, a region where quicksilver was mined first in 1824. The only recorded limestone production in the vicinity was in early days by Guadalupe Lime Company, who operated quarries and kilns on the south side of Capitancillos Creek 2½ miles from Guadalupe.

Permanente Cement Company (Black Mountain Limestone Deposits). The summit of Black Mountain, 2787 feet high, is near the southwest corner of sec. 13, T. 7 S., R. 3 W., about 15 miles due west of San Jose. It is the most prominent natural feature of the area of Franciscan rocks which extends southwest along the west side of the county, with a width here of 3¾ miles. Limestone deposits have been mentioned on the long eastward slope, on the west side and on the southwest flank. The production has been entirely from the more accessible eastern side in secs. 17 and 18, T. 7 S., R. 2 W., about 5 miles west of Monta Vista, where stone was quarried on a small scale to make lime for sugar refining. No detailed information was published up to the time the Permanente Cement Company began work in 1939 and the few analyses available were evidently of selected or sorted rock. It was known, however, that the limestone was generally more or less siliceous and for that reason no effort had been made to use it for cement.

The great mass of the mountain lies between the San Andreas fault and a branch fault called the Black Mountain fault which starts in Portola Valley several miles northwest and crosses the Page Mill road on the north side of the mountain, east of the main fault. This area between the faults was badly shattered by the 1906 earthquake (Lawson 08, vol. 1, pt. 1, p. 107) although it is not clear whether the abundant cracks found over the surface are to be attributed to the boldness of the topography or to the crushing of the wedge-shaped end of the fault block. According to the above report, "several days after the earthquake 345 cracks, large and small, were counted along the county road (Page Mill road) in a distance of less than 3 miles between these faults."

The interest in the Permanente plant was so great from the start that numerous technical articles on all phases of its operation have been

published. A list of these articles is given in the *Engineering Index*. For the purposes of this report, which is intended to give information primarily on the limestone resources of the state, the best of these articles is probably that by A. M. Kivari, entitled *Milling at the Permanente Cement Plant*, published first as Technical Publication 1359, American Institute of Mining and Metallurgical Engineers (1941) and later in Volume 148, Transactions, American Institute of Mining and Metallurgical Engineers (1942). A few details are given below from this article to fill out the meager information hitherto available about the Calera (Franciscan) limestone and the results of applying to its benefication the art of modern hydrometallurgy.

The limestone quarry is 45 miles south of San Francisco and 12 miles west of San Jose, at an elevation of 1850 feet. The overburden is only a few feet thick, and is easily removed. As the limestone is well fractured it is seldom necessary to use explosives. The quarry has been worked in benches by a 5-cubic-yard electric shovel which furnishes limestone to the conveying system at the rate of 5600 tons a day. The cement plant capacity of 12,000 barrels in early 1941 required about 3130 tons of limestone, 620 tons of "clay" (sandstone and andesite) and 100 tons of gypsum per 24 hours. The plant capacity was increased to 16,000 barrels late in 1941; capacity was increased again in 1943 and the plant became the world's largest. Further expansion is indicated in the accompanying information furnished by Permanente Cement Company. A stockpile of 550,000 tons is maintained for the cement plant and in the autumn, when the beet-sugar refineries demand large tonnages of limestone, another stockpile of 100,000 tons is made.

In a geologic report on the property, the late Professor C. F. Tolman and J. V. Neuman Jr., of Stanford University, estimated about 30,000,000 tons of proven and 18,000,000 tons of possible limestone. They distinguished two main types of limestone. The first is platy, dark blue gray, colored by hydrocarbon residue and usually finely crystalline with occasional coarsely crystalline layers or spots. The second type is white to gray, dense, and usually has a conchoidal fracture. It contains chert bands that lower the average $CaCO_3$ content to between 50 and 75 percent. They mapped the following beds:

1. Light, cherty and dark limestone, portions running 80 to 95 percent $CaCO_3$ and other parts 60 to 75 percent.
2. Sandstone and andesite.
3. Lower cherty white limestone requiring benefication.
4. Sandstone and andesite.
5. Dark limestone averaging 86 percent $CaCO_3$, about 200 feet thick.
6. Upper cherty light limestone.
7. Andesite.
8. White cherty limestone, varying in thickness from 10 to 160 feet, requiring benefication.
9. Sandstone, tuffs, and andesite.
10. Dark cherty limestone, 75 to 100 feet thick, requiring benefication.
11. Fine-grained andesite.
12. Complex folded and sheared limestone, sandstone and andesite, requiring benefication.
13. Undifferentiated Franciscan sandstone, shale and andesite.

The average chemical composition of numerous samples from four limestone beds was quoted by Kivari as follows, raw basis:

Average analyses, Permanente limestone

	1	2	3	4
SiO_2	29.23	12.86	7.24	4.18
CaO	38.04	47.48	50.96	52.74
Fe_2O_3	0.54	0.54	0.42	0.32
Al_2O_3	1.26	1.12	0.60	0.66
MgO	0.24	0.27	0.04	0.05
Ignition loss	30.66	37.70	40.48	41.90
Total	99.97	99.97	99.74	99.85
$CaCO_3$	68.4	85.12	91.39	94.67

The plant and methods used to beneficiate limestone for cement making in 1941 were described in detail by Kivari. This included the use of the Breerwood flotation process in which the only reagent used was talloel. It was saponified to the desired degree at the plant with caustic soda and diluted with water. About 0.8 of a pound of reagent was used per ton of dry solids. This process is no longer used.

*Current Developments, Permanente Cement Company.** In line with the current industrial growth of the West Coast, Permanente Cement Company is nearing completion of an expansion program which will boost its plant's annual production by some 500,000 barrels, or two million sacks of cement.

Officials of the Henry J. Kaiser-sponsored plant, located 10 miles west of San Jose, California, pointed out that the plant is already the world's largest cement mill and that the new facilities and changes effected will push its annual productive capacity to a peak of 5,500,000 barrels—10 percent more than its present rated capacity.

The availability of high-quality raw materials, limestone and clay, is partially responsible for Permanente's new production goal. Located immediately above the mill on plant property, Permanente operates a quarry from which it takes 6,000 tons of limestone in an 8-hour shift. Over a period of 1 year, a quarry force of 19 men move approximately 1,500,000 tons of limestone downhill to the processing plant.

Novel in operation of the quarry is the 48-inch conveyor belt by which rock moves to the mile-distant plant at the rate of 1,000 tons an hour. The plant throughout uses more than 4 miles of conveyor belting. After induction motors start the conveyors, generators driven by gravity flow supply enough electricity to operate a five-yard shovel in the quarry.

Limestone not suitable for manufacturing cement, is used to produce high-quality commercial rock for concrete aggregates, railroad ballast, highway paving material and other similar products.

Starting with changes in the raw grinding department, new facilities include four Fuller coolers for Permanente's kilns, an additional kiln feed slurry tank, new clinker conveying and crushing facilities, additional cement pumping equipment under the storage silos, and enlargement of the packhouse.

The California cement plant is not only the world's largest; it also employs revolutionary production methods made possible by varied equipment of special design.

A unique closed-circuit method of raw grinding in the mill building assures accurate control of fineness. This raw-grinding circuit produces slurry of which 95 percent will pass through a 200-mesh sieve that has

*Supplied by Permanente Cement Company, Kaiser Building, 1924 Broadway, Oakland 12, California.