the ripple index is approximately constant and is independent of flow intensity. For medium-grained sand statistical properties of the ripples and dunes other than the ripple index are required to correlate the characteristics of the bed configurations with flow parameters.

Two methods of analysis for medium sand have been developed. In the first, spectral analyses of profiles of the channel bed lead to a linear second-order Markov model which describes the essential statistical properties of the dunes. All the parameters of the model are simple linear functions of the water discharge per unit width of channel. One of the parameters, the standard deviation of the bed elevation about the mean, shows excellent correlation (correlation coefficient of 0.99) with unit water discharge for flows ranging from 0.7 to 10 cfs. per foot of width and for average dune lengths from 2–25 feet.

The second method of analysis consists of defining distributions of dune lengths, amplitudes, ripple indices, and angles of downstream faces, and relating the moments of these distributions to flow characteristics. All the distributions are skewed, and the skewness correlates roughly with flow intensity. This analysis gives useful indications of the variations in the geometric properties of ripples and dunes, but it is time-consuming and requires extensive data. Moreover, the parameters describing the ripples and dunes show only a crude relation to flow characteristics. Of the two methods, the spectral analysis appears to be more useful.

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R-MODE FACTOR ANALYSIS OF CINCINNATIAN (UPPER ORDOVICIAN) LIMESTONES

An *R*-mode factor analysis based on 20 petrographic variables observed in thin sections of 60 Cincinnatian biomicrosparrudites was made to determine genetic relations among several limestone classes. Thin sections were used for point-count estimates of whole and broken brachiopod grains, whole and broken bryozoan grains, disarticulated crinoid columnals, whole gastropods, and broken trilobite carapaces, as well as matrix (micrite and enclosed dolomite) and sparite. The correct volume of each measured variable lies within 5 per cent on each side of the obtained value with a 95 per cent confidence. The weight percentage of insoluble residue contained in each limestone sample also was determined. These measurements were combined into a 20 × 60 data matrix. The product-moment correlation coefficient was computed for each pair of variables, and the results were arranged in a 20 × 20 correlation matrix. Five statistically significant factors were extracted from the correlation matrix, which account for 82 per cent of the total variance. The geologic interpretations of the factor axes in order of extraction (decreasing significance) are: (1) mechanical energy gradient at the depositional site, (2) substrate firmness, (3) degree of lithification, (4) relative contributions of carbonate mud and skeletal grains to the sediment, and (5) Eh at or slightly below the depositional interface.

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STRATIGRAPHY OF PRODUCING GEOTHERMAL FIELDS

Natural steam production is found in reservoir rock overlain by impervious cap rock. These rocks may be volcanic, sedimentary, metamorphic, or plutonic. The age and composition of these rocks are not important but only Pliocene and Recent magmas are known as an underlying heat source. Reservoir rocks usually are highly fractured and rendered porous by solutions, must be of sufficient thickness (minimum 100 meters), and of an areal extent to sustain continuous production. Porosity values should be at least 10 per cent.

Man has utilized natural steam and hot waters throughout historic time. There are many present-day uses for natural heat, such as wood-pulp manufacture, evaporation of salt, space heating, and greenhouse farming. The first electricity made from natural steam was in 1905 at Larderello, Italy. Iceland, New Zealand, and Japan also were early users of geothermal energy. The Geysers in California is the first and only geothermal field generating electricity in the United States. Pacific Gas and Electric installed the first 12,000-kwh. turbine-generator in 1960, a 14,000-kwh. unit in 1963, and in 1966 installed a 27,500-kwh. unit for a total of 53,500-kwh. capacity. A fourth unit is planned in 1968 bringing the total to 81,000 kwh. The rapid industrialization and population growth of the western states, as well as the world, has led to increased demands for energy. The U.S. Bureau of Mines Circular 8230 states that, if the growth in electric energy consumption occurs as projected, construction of considerably more thermal-generating plants will be required. Natural steam probably is the cheapest source of energy.

Potential geothermal resources of steam are evacuated by five fundamental criteria: (1) source of heat; (2) regional and local structural features; (3) source of meteoric waters (to infiltrate and circulate to depth); (4) reservoir rock sufficient to retain geothermal fluids in volume; and (5) impervious cap rock overlying reservoir for trapping steam.

Facca and ten Dam recommend exploration in four stages:

1. Preliminary survey and selection of area (includes geological, geophysical, and geothermal information, stratigraphic studies, and porosity and permeability data).

2. Detailed survey of selected area (includes photogeology, volcanological and petrographic studies, hydrogeochemistry, and hydrogeology and gradient surveys).

3. Test drilling.

4. Probing and evaluating (includes output measurements and production tests).

Stratigraphic data of three producing geothermal fields for comparison are given.

Larderello field, Tuscany, Italy, discussed by Facca (1963). He described the sequence and conditions as follows: (1) basement rock, quartzitic and anagenetic; (2) reservoir rock, evaporitic dolomite with high porosity and permeability, Late Triassic; (3) cap rock, flysch-like, shaly, impervious *argille scagliose,* Late Cretaceous–early Miocene age; (4) no Recent volcanoes; (5) heat flow provided by a deep-lying magma; (6) temperature of producing zone is 200°C. (392°F.); and (7) surface hydrothermal activity occurs as hot springs and steam jets of 100° to 190°C. (212° to 374°F.)

Wairakei field, North Island, New Zealand, was described by W. G. Grindley (1961) as a volcanic region 240 kilometers long, a Recent graben filled exclusively by volcanites. Two volcanoes are active at each end of the graben. The impervious Huka Formation is the controlling factor in heat accumulation. The produc-