DISCUSSIONS AND COMMUNICATIONS.

SOME RECENT GEOLOGIC PHILOSOPHY.

In 1935, Professor Stille[1] published a paper of much interest to American geologists and especially to those of California, but of the portion of that paper dealing with West Coast Jurassic and later orogenies no digest will be here given, since the paper should be read in its entirety if the author's conclusions are to be fully appreciated. What is of general interest is the introductory and closing pages, which give his conclusions regarding the Earth's "orogenic and anorogenic times." As is now well known, Stille divides the tectonic history of the Earth into (1) relatively short and restless orogenic times when the mobile parts of the lithosphere are folded and elevated and their widths reduced one-third or one-half or even more; and (2) prolonged epeirogenic times of comparative crustal quiet, when the crust undergoes only undulations consisting of more or less wide elevations and subsidences (p. 179).

On page 182 Stille gives a most interesting summary table which shows 42 orogenic times now known to him, but he thinks that eventually we shall know 50. These post-Proterozoic orogenies are arranged according to their time occurrence, and the relative crustal effect of each orogenic event is indicated by the length of the lines grouped into four orders. Of these 42 orogenic times, 17 are not of great areal importance (11 are of least strength) and 25 have wide distribution, with 14 of the greatest historical value. The 42 pulsations Stille groups into three "tectonic eras." The present writer prefers a division into four such eras, taking out the two oldest, slight orogenies of late Cambrian and early Ordovician time (spread over 100 million years) to make a Sardisian era. Stille's three tectonic eras are: (1) Caledonian, with four orogenies (2— = minor, and 2+ = strong) spread over 115 million years (these estimates are the present writer's and on the basis of Stille's estimate of 580 million years); (2) Variscan, with 13 pulsations (8— and 5+) spread over 160 million years: and (3) Alpinian, with 24 times of folding (7— and 17+) during 205 million years.

These orogenies, arranged by periods and years according to Stille's table (with slight modifications by the writer), took place as follows: Cambrian, 100 million years, one very minor time of crustal folding: Ordovician, 80 m.y., 1 minor and 1 major event: Silurian, 35 m.y., 2+: Devonian, 40 m.y., 4 orogenies

[1] Stille Hans: Der Derzeitige Tektonische Erdzustand, Sitz. Preuss. Akad. Wiss., Phys.-Math. Klasse, pp. 179-219, 1935.

(3— and 1+); Carboniferous, 80 m.y., 6 (3— and 3+); Permian, 40 m.y., 3 (2— and 1+); Triassic, 30 m.y., 2 (1— and 1+); Jurassic, 35 m.y., 4 (2— and 2+); Cretaceous, 80 m.y., 8 (2— and 6+); Cenozoic, 60 m.y., 10 (2— and 8+). Arranged according to eras and years: Paleozoic, 375 m.y., 18 (10— and 8+); Mesozoic, 145 m.y., 14 (3— and 11+); and Cenozoic, 60 m.y., 10 (2— and 8+).

In these figures we see a decided acceleration of mountain making in the course of geologic time, and this conclusion is supported by the evidence shown in the progressively greater highlands and in accelerated erosion and sedimentation, as well as in the speeding up of organic evolution, evidenced by the ever quickened appearance of the higher grades of plants and animals.

In general, Stille thinks we can say that "in the transgressions and regressions of geologic time, the orogenic epochs bring about not only an enlargement of the continents in connection with the orogenic elevations of the fold zones, but likewise an increased and widened elevation of such regions as lie outside of the actual fold zones, i.e., through synorogenic increase of the epeirogenic results" (p. 183). This enlargement of the continents appears to the present writer, however, to be largely local in nature, and he believes that the areal sum of all lands was greater at the close of Proterozoic time than it is now. That much land has gone into the abyss is shown by Stille in the various submerged lands which he calls forelands, but the writer holds that the sum of these is considerably greater than the additions.

After the Nevadan orogeny of late Jurassic time throughout Pacific North America, Stille says, there was no other folding event for 100 million years, or not until Pleistocene time, when the Santa Barbara [his Pasadena] orogeny took place; all the other crustal disturbances of this long interval he holds are local epeirogenic events of the sort which he calls "germanotype." He says, further: "One is surprised to see in the region of Los Angeles a mighty stratigraphic series of the older Pleistocene folded with conformable Pliocene [together not less than 20,000 feet thick] and overthrust by older formations" (pp. 204-205). This folding represents the Coast Range Revolution of Bruce L. Clark. Even so, Stille thinks that Pleistocene time endured but 600,000 years, and that the Santa Barbara orogeny took place about 300,000 years ago. The writer holds with Lawson and others that the Pleistocene endured at least one million years and believes that it will eventually be shown to have been two and perhaps three times as long. Stille says he was not surprised to learn that the Santa Barbara orogeny is not yet completed, even though what we see of it has taken something like 300,000 years to accomplish. Taking this figure and assuming that there were 50 orogenic times, Stille estimates that the actual time consumed in all these crustal

movements appears not to have included more than 15 million of the 580 million years since the beginning of the Cambrian period. It is the writer's opinion, since he thinks that Stille much underestimates the duration of the Pleistocene, that the actual duration of the 50 catastrophic events may have exceeded 50 million years. After all, this is less than one-eleventh of geologic time since the Proterozoic era; however, he agrees with Stille that the duration of all the climacteric diastrophisms is but a small part of the above estimates. In conclusion, our author says *we are living just after the closing stage of a catastrophic time.* Therefore we have all about us the phenomena of abnormal geologic conditions, and hence we cannot use the present for the correct appraisal of the normal environmental conditions throughout most of geologic time (p. 214).

In this connection, attention must also be directed to another recent and similar paper, by Professor Von Bubnoff,[2] whose results, the present writer is pleased to note, were largely stimulated by the latter's work of 1931.[3] Von Bubnoff points out that the rate of sedimentation has increased with time, and that it is from four to five times more rapid locally in the Cenozoic than in the Paleozoic (p. 508). This increase appears to indicate a quickened erosion due to increased height of mountains, and likewise a quickened succession of the tectonic cycles (of which he has six in place of Stille's three) from 175 million years in the first cycle to 25 million years in the late Cenozoic-Present one. The time relation of these tectonic cycles to one another he expresses in the following ratios: 9:7:4:2 1/2:1. Bubnoff holds that the folding "ever concentrates into narrower zones and thereby gains greater intensity for what it loses in extensiveness" (p. 510). The writer also sees greater extension of the Paleozoic seas, less areal extent of the highlands, and accordingly a lessened rate of areal sedimentation—conclusions which the American Paleozoic formations show clearly. But why do these cycles occur, and why do they quicken in geologic time? These questions are not yet answerable, but Bubnoff leans toward subsurface magmatic flowage as the probable answer to the first question, and to the speeding up of the periodic increase of heat, as first announced by Joly and later modified by Holmes, as the probable solution for the second question. Bubnoff does not believe in an equal duration for the tectonic cycles as do some geologists, but agrees with Schuchert that they have quickened in time. Finally, Bubnoff says: "The degree of biologic differentiation and its speeding with time comes clearly into view with time and attains its unmistakable

[2] Von Bubnoff, S.: Das Alter der Erde und der Gang der Erdgeschichte, Die Naturwiss., Heft *29*, pp. 506-511, 1935.

[3] Schuchert, Charles: Geochronology, or the Age of the Earth on the Basis of Sediments and Life, in Bull. 80, Nat. Res. Council, pp. 10-64, 1931.

climax in the Cenozoic. The direct interrelation of Earth history and life development is nowhere more clearly seen than in the above facts. However, Schuchert is correct when he says that the degree of specialization in the Cambrian was already far advanced [note the advanced state of differentiation among the arthropods, the presence of gastropods, and even of cephalopods and annelids] and that a much longer time [at least 1000 million years] was necessary to bring into existence the Cambrian grade of marine invertebrates" (p. 511).

CHARLES SCHUCHERT.

PEABODY MUSEUM,
YALE UNIVERSITY.