PRELIMINARY NOTE ON GEOLOGIC STUDIES OF THE PACIFIC SLOPE IN SOUTHERN PERU*

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SINCE 1942 the writer has had opportunity to make numerous observations on the geology of southern Peru and to compile a reconnaissance geological map of parts of the departments of Arequipa, Moquegua, and Tacna. The area adjoins the Titicaca region, mapped by Dr. N. D. Newell. The combined maps cover a broad zone extending from the coast northeast across the crest of the Andes past Lake Titicaca. On the Pacific, stratigraphic and structural data have been collected. Marked differences in the stratigraphic sequence at Arequipa as compared to that at Puno have been noted, but primary emphasis has been placed on the study of the extensive and varied phases of igneous activity, both intrusive and extrusive, developed throughout the region. The work is to continue through July, 1946 in connection with field studies at the University of San Agustin in Arequipa.

STRATIGRAPHY.

The pre-Tertiary stratigraphic history of the region is somewhat obscured by the intrusion of large igneous bodies which in many places have cut out or metamorphosed the earlier sedimentary rocks and volcanics. Exposures of the older rocks are further limited by the overlap of Tertiary terrestrial deposits and by Tertiary to Recent volcanics. There are, however, sufficient exposures to make possible the presentation of the generalized stratigraphic sequence in Table I.

The oldest formation in the region is the Charcani gneiss, which outcrops in the Chili valley between the volcanic masses of Misti and Chacchani and also makes up much of the coastal hills between the Tambo River and Camaná. The most typical rock is an injection gneiss formed by the intrusion of a granitic magma into an earlier sedimentary series. The

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TABLE I

Stratigraphic Sequence

Age	Formation and Description	Thickness (Meters)
Quaternary	Moraines, and other glacial deposits, volcanics, alluvium, marine terrace deposits	Variable
Quaternary and late Tertiary	*Sillapaca volcanics*: dacitic, andesitic, and basaltic volcanics	1000
	Moquegua formations Terrestrial sandstones, and conglomerates. Highly variable thickness	1500
Tertiary	*Tacaza volcanics*: Massive dacite tuffs over a thick series of basalt and andesite flows, agglomerates, and tuffs	4000
Cretaceous (Lower?)	*Yura formation*: Interbedded quartzite and shale; thin limestone beds in upper half	1600
Jurassic	*Socosani formation*: Black shale overlying gray, highly fossiliferous limestone	400
Late Paleozoic	*Chocolate formation*: Andesitic to basaltic volcanics with some limestone, sandstone and shale	900
Pre-Cambrian (?)	*Charcani gneiss*: Granite gneiss, in part an injection gneiss	?

gneissic banding is remarkably even over considerable areas, with dips rarely exceeding 35°. South and southwest of Arequipa, however, the layers are highly contorted. At Mejia, on the coast, the evenly banded gneiss is cut by a coarse-grained granite which grades into the granitic layers of the injection gneiss.

The contact of the late Paleozoic Chocolate formation with the Charcani gneiss has never been observed, but the distribution of outcrops is such as to lead to the assumption that the Chocolate formation overlies the gneiss unconformably with no other formation intervening. The Devonian shales and quartzites, which are thick in parts of the Titicaca basin, do not occur southwest of the continental divide. The Chocolate formation is composed chiefly of volcanics, both flows and pyroclastics, with associated sedimentary rocks, including isolated coral reefs at the type locality. The exact age of the formation is not known, but sufficiently well pre-

served fossil suites have been collected from the sedimentary rocks to assure a specific dating in the near future. The volcanics of this formation are well exposed at the Chocolate quarry near Yura, at Socosani, and near Cocachacra in the lower Tambo valley.

Intrusive rocks ranging from diorite through granodiorite to granite are tentatively correlated with the late Paleozoic vulcanism. These plutonic rocks, which are extensive at the north end of the Caldera Range near Arequipa and in the coastal hills near Ilo, are distinguished from the Tertiary intrusives by the presence of a moderate foliation, by the dominance of biotite over hornblende, and by widespread epidotization. In general they are of coarser grain than the definitely Tertiary plutonics.

The Jurassic Socosani formation rests disconformably on the fairly even surface of the Chocolate volcanics. The lower part of the formation is largely gray limestone, with occasional sandstones and thin shale beds. At two localities a thick sandy shale containing abundant belemnites has been noted. At Socosani the limestones are capped by more than 40 meters of black concretionary shale. The formation is highly variable in thickness, ranging from 224 meters at Socosani to about 400 meters only 28 kilometers away, near Tiabaya. It is possibly to be correlated with the Lagunillas formation, which outcrops near the west edge of the Titicaca area.

The Yura formation, probably of lower Cretaceous age, is the most extensive of the Pre-Tertiary sedimentary rocks. It overlies the Socosani formation with disconformity or very slight angular unconformity. Alternating quartzite and shale beds averaging one to two feet thick make up most of the formation, but in the upper part, particularly in the region south of Arequipa, richly fossiliferous limestones occur. At various horizons a poorly preserved ammonite fauna is found in pink shales and gray, limy quartzites. The black shales throughout the formation contain plant remains.

The Yura formation outcrops in a broad band extending from Ramal, at the western base of the Caldera Range, southwest to Carumas. Large areas of the formation are also known in the upper Siguas valley and in the Majes valley.

A lower Cretaceous age has been tentatively assigned to the Yura formation; the exact range represented should be defined

by the study of adequate fossil collections made at the base and top of the sequence.

In the upper Siguas valley, resting on the Yura formation nearly or quite conformably, is a formation of red beds with some salt and gypsum. These beds have been little studied, and no fossils are known from them. It is possible that they are to be correlated with part of the middle Cretaceous in the Puno area.

TERTIARY VULCANISM

On the Pacific slope in southern Peru the Tertiary is marked by great accumulations of volcanic material. A thick earlier series, the Tacaza volcanics, is separated from a later series, the Sillapaca volcanics, by an important unconformity.

The general relations of the Tacaza volcanics in the Titicaca basin were described by Newell in the preceding paper. The unconformity with the underlying formations in general appears less marked between Arequipa and Moquegua than in the Puno area. The thickness of these volcanics is great wherever they have been observed. The predominantly basaltic sequence in the Santa Lucia area gives away, however, to andesites in the Carumas area, and even includes some latites and rhyolites near Moquegua.

Wherever their base is exposed the Sillipaca volcanics are seen to rest with marked unconformity on Tacaza and older beds. After the earlier vulcanism there was strong deformation; a mature to late mature surface was developed over much of the region before renewed vulcanism and uplift took place. The relation between the beginning of this general uplift of the Andean zone and the beginning of the Sillapaca stage of vulcanism is not yet clear. Present evidence seems to indicate, however, that the volcanic activity was renewed during or soon after the first upward shift.

At the start of the post-Tacaza erosion period a broad depression at or close to sea level existed between the Andes and the coastal hills. This depression was filled with terrestrial deposits, including sandstones, conglomerates, and gypsiferous shales derived from the erosion of Tacaza and older rocks from the Andean side of the basin. These terrestrial deposits are for the present grouped together as the Moquegua formation. Much additional work will be necessary

before relations between this formation and the older coastal terraces on the one hand and the Sillapaca volcanics on the other can be determined. Southeast of Moquegua andesite flows rest with apparent conformity on the Moquegua formation, while near Vitor, tuff beds are interbedded with the highest beds of the formation.

The term Sillapaca is used to include all post-Tacaza volcanics. This group of rocks is composed of a great variety of deposits, from a thick series of flows and pyroclastics covering great areas and already deeply eroded, to fairly recent basalt domes south of Cailloma and perfect cinder cones along a tributary of the Majes river. Of particular interest is a white to salmon-colored tuff which covers some 450 square kilometers northwest of Arequipa. This tuff is made up of a series of thick beds which have the characteristics of the pyroclastic deposits left by *nuées ardentes*, as first recognized by Fenner (1940). Repeated outbursts from the lower slopes of Chacchani, an old multiple volcano, piled up the tuff to a thickness of at least 230 meters (740 feet) in some places. Certain beds show the effects of fusion, and are welded tuffs. In a few places silicification of the tuffs has been noted.

TERTIARY INTRUSIVE ROCKS.

Plutonic intrusive rocks of Tertiary age make up a large proportion of the western foothills of the Andes. In this region most of the intrusives are believed to be related to the Tacaza stage of vulcanism; they penetrate all pre-Tacaza formations, and, in some places the Tacaza volcanics themselves, but are truncated by the post-Tacaza erosion surface. The Moquegua formation rests with marked unconformity on all the plutonic rocks with which it is in contact. Farther into the Andes there are numerous smaller intrusives which are obviously related to the later, Sillapaca, stage of vulcanism.

In the foothill belt hornblende diorite and quartz diorite appear to be the dominant rocks, but many other types, such as granodiorite, granite, syenite, and quartz monzonite have been distinguished in the field. Cutting the larger masses of diorite are irregular stocks of "quartz porphyry," a rock with abundant subhedral to euhedral quartz grains in a fine, light colored matrix.

The later intrusives in the highland regions are chiefly hornblende diorite, syenite, and quartz monzonite. In two places near Santa Lucia erosion has cut deep into volcanic necks filled with unbedded volcanic breccia of dacitic composition.

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