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GEOLOGICAL NOTES ON WESTERN SAMOA

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ABSTRACT

Four of the six main volcanic formations forming the bulk of Western Samoa comprise interbedded pahoehoe and aa-like scoriaceous rubble in a ratio of between 1 : 2 and 1 : 4. All presumably have very similar bulk densities. The Lefaga Volcanics have substantially the highest void ratio, but are of limited distribution. The Fagaloa Volcanics, the oldest of which have reverse polarity implying an age greater than 1,000,000 years, form much of Upolu and Savai'i at depth, particularly in the east. They have significantly lower void ratios and higher densities than most other rocks, due to compaction before erosion, to vesicle filling, and to deep weathering. There is thus a marked tendency for bulk density to increase with depth, made the more marked because relatively dense vitric tuffs, formed like the young Vini Tuff, by eruptions directly into the sea, are presumably more common in the lower part of the volcanic pile.

Faulting features include the major 110°-aligned fractures of the Pacific sea floor and minor gravity-induced faults, particularly on Savai'i, caused by collapse of the flanks of the volcanic pile. All are the sites for subsequent volcanic eruptions and for the congealing of lava into closely-packed dikes.

Major unconformities, possibly corresponding to abrupt physical changes, occur within and above the Fagaloa Volcanics.

INTRODUCTION

These notes supplement a geological summary (Kear, 1967, after Kear and Wood, 1959) by presenting a simplified geological map (Fig. 1) and an account of those geological features that are of particular relevance to geophysics. All papers published since Kear and Wood (1959) are given in the reference list, including Fox (1962), Richard (1962), and Wright (1963) not referred to elsewhere in this paper.

RELATIVE BULK DENSITY AND FLOW TYPES

General

The relative bulk densities of the several formations depend principally on the initial void content of the rocks in bulk, and on the degree to which the voids have been eliminated. All rocks are basaltic, apart from minor andesites in the Fagaloa Volcanics, and most rock types of the six major volcanic formations (i.e., all but the Vini Tuff) are all similar. They com-

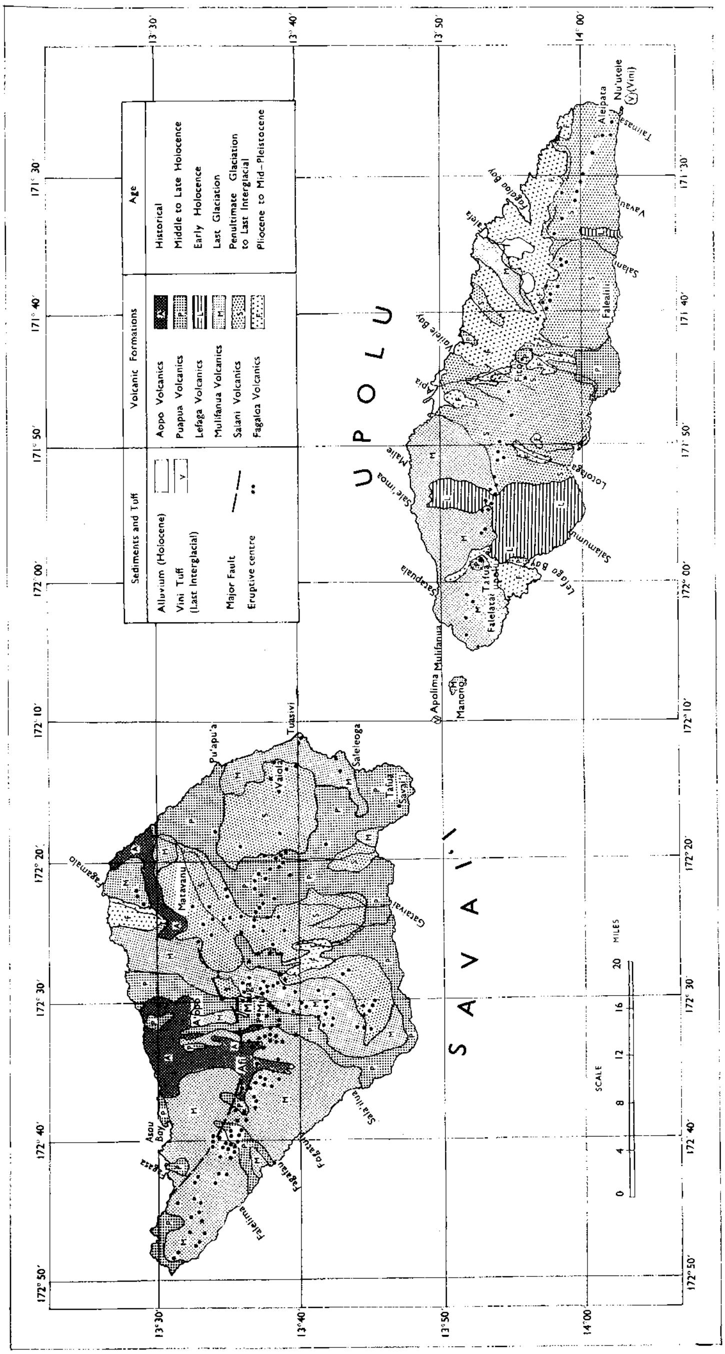

FIG. 1—Simplified geological map of Western Samoa.

prise alternating massive lava flows (pahoehoe), and rubbly scoriaceous material that is either true aa or the fragmental base to pahoehoe. The formations differ from each other in the relative proportion of massive lava, the presence of dikes, the effects of compaction (i.e., of collapse of voids due to the weight of overlying rocks), the infilling of cavities, and the depth of weathering.

It should be stressed that differences in bulk densities between different localities in the same flows are likely to be greater than the average differences between the formations. The descriptions below concern firstly the several formations as each occurs at the ground surface, and secondly those features at depth that are common to all formations.

The very considerable void content and permeability of these rocks is illustrated by the hydrological characteristics of those that were encountered in the digging of Afia Well. This was sunk to a depth of 130 ft through interbedded lava, rubble, and rare coral, and commenced in Mulifanua Volcanics. The water table was measured as rising only 1 ft 6 in. from the coast to the well, which is $1\frac{1}{4}$ miles inland. No drawdown could be measured when pumping at a rate of 2,000 gallons per hour (Kear and Wood, 1959, pp. 71–2).

Lava tunnels do occur, but are not a common feature.

Fagaloa Volcanics

Fagaloa Volcanics have by far the lowest void ratio of all six major formations. Flow thicknesses range from a foot or so to 100 ft, with the rubbly material between two to four times as thick. These values are probably close to the average for all formations, but the void ratio of the Fagaloa Volcanics is lower than that of other formations; firstly, because erosion has removed considerable thicknesses of overlying rock and has thus exposed rocks that have been compacted by overburden; secondly, because dikes are common, due both to the effects of the erosional exposure of deeper areas of the Fagaloa volcanics and to the effects of intrusions associated with later volcanics; thirdly, because all vesicles and similar cavities have at least a coating of zeolite, or less commonly calcite, and some cavities are almost completely filled; and fourthly, because clays resulting from the very deep weathering have partly filled the spaces between rubbly fragments. In addition, the Fagaloa Volcanics is the only formation, apart from the minor Vini Tuff, in which vitric tuff is relatively common. This has a significantly higher bulk density than intercalated pahoehoe and rubble.

Salani and Mulifanua Volcanics

Salani and Mulifanua Volcanics are very similar to each other, differing only in the Salani's having a slightly greater thickness of surface weathering (a little over 12 in.), and most, rather than a few, vesicle surfaces coated with a zeolite film. Neither formation is eroded far enough to expose either dikes or compacted rock. Both give the impression of including a higher ratio of pahoehoe flow to rubble than the Fagaloa; but this is probably illusionary because most surface flows are pahoehoe. In those few places where rivers have cut into Salani rocks they have exposed a high proportion of rubbly rock; and the extreme permeability of Mulifanua rocks shown by the Afia Well (*see above*) implies a considerable thickness of rubble.

Lefaga Volcanics

Lefaga Volcanics are relatively unweathered, and without cavity filling. They are assumed to have the lowest bulk density of any volcanic formation mainly because the ratio of lava : rubble is as low as possibly 1 : 10.

Puapua and Aopo Volcanics

Puapua and Aopo Volcanics are both unweathered and without cavity filling. Their characteristics will be close to, and perhaps indistinguishable from, Salani and Mulifanua rocks.

Vini Tuff

Vini Tuff is of very restricted occurrence, and is very different from the six main volcanic formations, because the eruptions that gave rise to it took place in the sea. It comprises a dense vitric tuff, lacking voids, except within the few small included basalt fragments. Although individual rock specimens would undoubtedly be less dense than those of pahoehoe flows, the bulk density of this formation would probably be higher than for any major formation.

Bulk Density at Depth

The above comments regarding bulk density relate largely to rocks close to the surface. Below this, the effects of compaction, the increasing presence of dikes (e.g., lava conduits), and the several factors mentioned above that lead to the infilling of voids, all cause increasing densities with depth. In addition, the accumulation of glassy rock of the Vini Tuff type, must have been universal in the early stages of development of new land from sea. Hence such material is likely to be more common at depth, as is clearly the case with the Fagaloa Volcanics. It may also be common in the central part of the island, up to say 500 ft above sea level, where eruptions into the sea would have been possible during early Pleistocene high sea levels.

Moore (1965) has noted a reduction of vesicularity and an increase of bulk density in samples of lava dredged from increasing depths of up to 5 km off Hawaii. The same tendencies presumably occur in the lavas of Samoa.

GLASSY TEXTURES

The six main formations were all erupted predominantly on land and under similar conditions; but cooling rates were not everywhere the same. Near the cones, and over much of the land areas of lava flows, cooling was slow enough to produce a crystalline groundmass around the ubiquitous olivine and less constant feldspar and pyroxene phenocrysts. In restricted parts of the flow, where it entered water-logged swamps or a lagoon, cooling was more rapid, and is shown by a glassy groundmass—perhaps with only olivine phenocrysts. Thus, glassy textures tend to be more common around the margins of the island, as those margins were present at the time of eruption.

The ultimate case of glassy texture is shown by the Vini Tuff, which had its point of eruption at sea. Much of the volcanic pile around its fringe, at depth, and even above sea level in central areas, would consist of similar material.

FAULTS

The 110° alignment of Upolu, and to a lesser extent of Savai'i, is almost certainly associated with a major fracture in the floor of the Pacific. It is unlikely that this feature could be recognised by geophysical methods, apart from the indirect effect of a clustering of volcanic lava conduits, and therefore of dense dikes, along its length. Some smaller faults, that are essentially minor collapse features within the volcanic pile, may well show up geophysically however. On Upolu a large fault of this type extends east–west along the south-east coast, and the down-faulted part is wholly below sea level (Kear and Wood, 1959, fig. 32).

On Savai'i, in contrast, collapse faults are inferred to be common, and have contributed to the bulbous shape of the island. The most important occurs in the north. It is curved, open towards the north, and the northern segment of the island here has slipped substantially. Both of the two major historic eruptions (1760 and 1905–11 A.D.) have occurred along this fault, which may have caused significantly less dense rocks to the north to abut against more dense rocks to the south. It should certainly have caused a concentration of lava conduits along its plane.

PALEOMAGNETISM AND AGE

Tarling (1962, 1966) has discussed the paleomagnetism of the Samoan Islands and has made inferences regarding age. These are in accord with the stratigraphy developed by Kear and Wood (1959) from erosional forms. All formations younger than Fagaloa were considered no older than the Last Interglacial, and their normal polarity was expected. The Fagaloa Volcanics were considered Pliocene to mid-Pleistocene and to be generally older in Upolu than in Savai'i. Tarling found normal polarity in Savai'i, and in the younger Fagaloa of Upolu, which was noted by Kear and Wood (1959, p. 36) as still showing part of the original cone surface. The older Fagaloa, which had no part of the original cone form remaining, was shown to have reverse polarity, and was therefore inferred by Tarling to be older than one million years.

Tarling's work is important, not only in describing the paleomagnetism and confirming the stratigraphy of Western Samoa, but also because it may imply that the break between upper and lower Fagaloa is of major importance, perhaps comparable with that between the Salani and the Fagaloa. There may be important physical changes at both these contacts.

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