GEOLOGY OF THE SAMOAN ISLANDS

BY HAROLD T. STEARNS

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the western end of Ta'u was lost. A total of 10 days was spent on Upolu in 1944 and in 1945 in reconnaissance by airplane, automobile, horse, and foot. A boat trip was made from Ta'u to the lava flow of 1945 on Savai'i in 1949. An airplane reconnaissance was made of Savai'i in 1943.

**Previous Investigations**

Davies (1855, p. 307-316) was the first geologist to describe Savai'i. His time field work was short except on Upolu. He noted that Savai'i was a large but

upholstered hump-like mass of basaltic lavas. On Upolu he explored the coast of Tapu岛上 and the crater lake of Lomololi, noted dips of 45° in the lavas; recorded the Reitei lava on Aitu, on the north coast across the island from Aitu, and Lauteri; observed that Neulote and Nulau islands and Tapae Point were in the crater containing isolated coral fragments, recognized the marls at the main quarry near the island with its line of coast; pointed out the youthful character of the western district and the greater age of the central parts, especially the northern side; was unable to believe that subduction had occurred but could not prove it on land and had no evidence of an oceanic crust; and stated that the latest eruption occurred in 1939.

Chamberlin (1924, p. 145-154) agrees with Mayow that a drowned barrier reef surrounds Tuvalu island but disagrees with Daly that there is evidence that the reef is real. He believes the reef is not a wave-cut and wave-built shelf he observed in 400 feet of water and probably more, and too deep to have been formed under the conditions of glacial eustasy without subduction; also, that this could indicate the former period of great stability. His final conclusion supplements rather than contradicts Davies' theory of coral reefs. He noted also that the lava flows radiate from various volcanic foci.

Daly's (1924, p. 95-154) work resulted in many valuable conclusions regarding magnetic differentiation. Macquoid has summarized his contribution to the geology of Tuvalu. Daly's observations were that:

1) Tuvalu is a single en
gene;
2) the main mass of Tuvalu is on the leeward side, is no younger than its forearrest and is perhaps Pleistocene or older; and
3) Tuvalu is a drowned barrier reef surrounded by Tuvalu island.

Daly's work led to the present stage in the growth of the volcanoes; and the possible means of t
eruption which were found in large funnel-shaped craters largely filled with basaltic breccia; the many fragments lie in the lavas, but their relation to the breccia plug is not; none, about 400 meters from the shore cliffs; and there has been a late eruptive, which he estimates as 6 meters. He mapped some of the lava beds but did not find the source of the lava. He recorded no faults.

Tuvalu contributed the following scientific information of its importance:

1) Olau and Olaua Islands are two islands of a small tectonic island originally the island of Tavau; and
2) Oku and Oksa reefs are two islands of a small tectonic island originally the island of Tavau; and
3) Tavau, 100 meters or more high, has been cut by the sea. He pointed out how the height of the high cliffs; (4) lavae of collapse; (5) lavae of collapse; (6) lavae of collapse; and (7) lavae of collapse.

Tuvalu's scientific contributions to the knowledge of the geology of Tuvalu are:

1) Olau and Oksa reefs are two islands of a small tectonic island originally the island of Tavau; and
2) Tavau, 100 meters or more high, has been cut by the sea. He pointed out how the height of the high cliffs; (4) lavae of collapse; (5) lavae of collapse; and (7) lavae of collapse.
2. A profound angular unconformity separates a dike complex and later lava extrusions from 7 miles southeast from Mono Bay.

3. A fault of great displacement bounds a caldera 6 miles across in the Pueblo Volcano.

4. The faulting is a drowned river valley that owes its great size to tectonic action, chiefly in weak tuffs, along the base of a caldera fault scarp.

5. The Matilas plug is bordered by contemporaneous friction breccia and cut through an older series of explosive tuffs and breccia interbedded within the tuff.

6. The Pinto plug pushed upward through a thick series of nearly horizontal tuffs that had filled in most of the Pago caldera and not through a round-shaped pipe filled with tuffs.

7. A caldera 3 mile in diameter exists in the Abajo Volcano.

8. Remnants of a coral reef that grew during a stand of the sea 5 feet higher than the present.

9. Maps of vents from which the Lassen volcanoes issued.

10. Discovery of an unconformity between the recent tuffs.

11. Rounding of about 60% of tuffs and 40% of lavas.

12. Description of a dike infilled with breccia ash.

13. Description of two dike filled with a massive dacite.

14. Maps of heat plugging and one dike of trachyte not previously recorded.

15. Summary of records of 25 boulders showing that the fringing reefs in Pago Pago Bay are built almost entirely of calcarous silt and sand.

16. Evidence that the absence of extensive reefs is due to rapid submergence in late Pleistocene time.

17. Evidence that most of the drainage is controlled by the structure of the volcanoes.

**GENERAL CHARACTER AND AGE OF THE ROCKS**

**Tuzio** is chiefly basaltic volcanic rocks with small amounts of trachyte, andesite, andesite, andesite, andesite, andesite, andesite, andesite, andesite, andesite. The main bowl of the volcanic rocks appears from its weathered and rounded condition to be Pleistocene or radiometrically. For brevity these rocks will be called Finocone. Plant fossils from the tuffs give no clue to the age of the rocks. Fresh basaltic tuffs and lavas have been found flat plains on the southeast side of the island. They appear to be Brinno tuff zone of Rietto age also known as Tucano Island. The andesite and basalt with other unconsolidated or weakly consolidated lavas. Two good wash borings to depths of 50 to 80 feet across the fringing reef adjacent to Pago Village revealed that the upper 20 feet of the bed is almost entirely slightly weathered calcarous silt and sand, except at the surface where there is a weathered cemented, calcareous, silty, and sandy. Twenty-five holes were made these two flats in 1910.

The Finocone rocks are grouped about five volcanic loci which, for convenience, have been named. The age relation of the rocks of each locus to the adjacent rocks further study. A stratigraphic section is given in Table 1.
### Table 1—Continued

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
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<tr>
<td>Lower surface</td>
<td>Lava which is composed of blocky, cold-looking basaltic bombs, some of</td>
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<td></td>
<td>which are tilted to the side, giving a step-like appearance. The size of</td>
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<td></td>
<td>the bombs ranges from 20 to 50 feet. The lava is dark gray to black, and</td>
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<td></td>
<td>it is covered with a layer of white or yellowish ash. The surface is</td>
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<td></td>
<td>rough and scoriae are common. The lava is very viscous and flows slowly.</td>
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**Note:** The lava flows are highly viscous and slow-moving. The surface is rough and rocky, with frequent pumiceous material.

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### Table 2—Continued

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**Note:** The lava flows are highly viscous and slow-moving. The surface is rough and rocky, with frequent pumiceous material.
case, subsequently buried by lava flows. The dike complex extends to the present dike complex exposed on Oahu Island. Additional field work is needed to fix this area.

The lava flows between the dikes are thin and lack on the west side of the fault, and quartz dikes are thin and lack on the east side of the fault. Apparently this is due to faulting, for the amount that is missed cannot be accounted for.

![Diagram](image)

**Figure 2—lava flow thickness in the Macunaua dikes complex, Tutuila**

Lava flows in all stages of differentiation indicate that the intrusive centers of the complex are thin and lack on the west side of the fault, due to faulting. Shown by repeated intrusion, and swells downward into the underlying dikes at a breccia.

**OLOMAUS VOLCANISM**

The Ohomua volcanics are chiefly basaltic and cover about 1 square mile east of the island. The Island Peak, altitude 2104 feet, is a large fissure and crater rifts, about 200 feet above, and remnants of associated basalt cones are exposed along the coast. Cape Matiu is in the plug. Polyhedral cinder cones are interbedded with the basalt flows. A large partly eroded cinder cone lies at an altitude of 2380 feet. The topographic map for the area is shown on the large amphibolite-forested area on Aho. Additional work on Aho is very scarce in the area. Near the head of the basaltic area, a wide, flat, broad-topped cinder cone rises to a height of 1500 feet. The Lava plug lies on the near side of the Olohu. Ohomua Volcano was probably built on the top of Aho Vulcano during the closing phase of the Ohomua volcanic activity in Tutuila.

The basalt of Aho Vulcano may overlie the west slope of the Ohomua cone, but the unconformity was not found. Both volcanoes may have been contemporaneous. Lava on the proximate forming the east.

**Table 1—Location of rocks in the Aho Vulcano Complex**

<table>
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<th>Layer</th>
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<tr>
<td>1</td>
<td>N. 40° E</td>
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<td>N. 40° E</td>
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<td>3</td>
<td>N. 40° E</td>
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<td>14</td>
<td>N. 40° E</td>
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<td>15</td>
<td>N. 40° E</td>
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**Note:** The Olohu Volcano is similar to the Aho Vulcano, but the unconformity was not found. Both volcanoes may have been contemporaneous. Lava on the proximate forming the east.

**Alaun Volcanics**

The Alaun volcanics include all the thin-beded, chiefly olivine basalt, and the dikes, breccias, and flows, and lava flows forming the Aho Vulcano. They cover about 1 square mile east of the Aho Vulcano and are named from the village of Alaun in the center of the volcanics (Fig. 1). They appear to be partly on the east side of Aho Vulcano and the north side of Aho Vulcano and the north side of Aho Vulcano. About 100 individual dikes and 1 fault are exposed in the 200-foot interval of the basement on the north side of Alaun. No exposures occur in the 75 feet of the dikes. The revet is from west to east.
Koh is not exposed in the flat swamp by Aholu Village. Where the road
traverses the swamp, 91 aerial and 3 lands of built brecias were noted,
whose thickness is about 1250 feet even though rock is exposed for
only about half the distance. Most of the rocks in this stretch trend
N. 90°-120° E. Beyond, the number of rocks decreases rapidly.

Taka brecias containing blocks up to 3 feet across and dipping 25° S.E.,
terraced ledges in the road cut about 300 feet southeast of Fagana. These
were cut by N. 50° E. and dip 80° S.E. It suggests that the walls of
Aholu Volcano, the approximate position of which is shown
Plate 1. The site of the caldera decreases in height to the northeast,
which suggests that the southwestern half of the caldera was considerably
less than the northeastern half at the time of its extension. It is now eroded and absent.

**FAGA VOLCANIC SERIES**

**General statement.** — The Faga volcanic series includes the extra-caldera lavas,
plugs, center cones, vitric tuffs, tefhite tuffs, and breccias; and the intra-caldera
dikes, plugs, center cones, tuffs, and breccias. These were not available to map all of
but those shown on Plate 1 indicate their distribution.

**Extra-caldera lavas.** — The extra-caldera lavas consist of two distinct
types: the axial and transitional lavas that are reddish-brown to yellow and
were scaled. They are the pre-caldera primitive olivine basalts and their
nodules and dikes of and phonolite, and the post-caldera differentiated lavas;
chiefly phonolite, andesites, and trachytes and their associated dikes and phonolites.

**Intra-caldera lavas.** — The intra-caldera lavas are essentially the pre-caldera.
Although a few gravel and basaltic deposits occur locally. The post-caldera
lavas have been mapped separately at Fagana and Heta (Plate 1). The best exposed
extra-caldera rocks are along the north coast in the near continuous set of
lavas, dikes, and other details plotted on Plate 1 along that coast were not
mapped from a moving boat; hence, small errors in strike may have been
introduced which would not be significant unless the adjacent lavas were probably
aligned. Several structures are exposed along the coast between the rocks because
these are cut through the caldera of the volcano. Many dikes and faults are
in the lava flows that cut the volcanic thickly. The widest basaltic dikes
in these volcanics measure 60 feet across. It trends N. 50° E. and cuts out
wedges near the northeast corner of Fagana. Fifty feet north of
faults with large but unmistakable displacement trending N. 50° E. and dip 55°
S.W. A dike 30 feet wide cuts across in the west side of the bay hill's mouth of
Point Nelson, not far below the level at which it has erupted. Such wide
are rare and are probably local swellings. Very little structure is exposed
so Masafu repos lava but the microstructures only of their shores are visible.
Along the west half of Aholu Village on the slope the basaltic
is highly sensitively up to 4 inches across and cut pyroxene crystals 1 inch long.
Such occurrences exist in Fagana and Aholu. They were mapped by
traverse and boring at low tide. The details follow:

**Fagana Bay.** Excellent exposures of pre-caldera thin-bedded primitive

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**Image information:**

Plate 1: Field Contacts at Fagana, Fagana, and Point Nelson. A large rift running from the northwest to southeast.

---

**Diagram details:**

- Fagana Bay:
  - Excellent exposures of pre-caldera thin-bedded primitive
  - Rift running from northwest to southeast

---

**Textual content:**

- Extra-caldera lavas:
  - Two distinct types:
    - Axial and transitional
    - Reddish-brown to yellow
- Intra-caldera lavas:
  - Essentially pre-caldera
  - Small errors in strikeแต่ may have been introduced
- Structures exposed along coast:
  - Wide basaltic dikes
  - Dikes and faults in lava flows
  - Eruptions at Point Nelson
  - Wide dikes rare and local swellings
  - Microstructures visible in shores
- Map areas:
  - Fagana Bay: Excellent exposures of pre-caldera thin-bedded primitive
and lava, and a slip complex and an associated fault form the shore of Euga (fig. 1, inset B). The circular form of Euga Valley suggests a subaerial center at the site of the Pagan Volcano subsequently eroded by stream erosion, but the inset all the lava beds forming the bay dip away from the Pagan caldera rim and neither cross-parallel nor cross-parallel and cross-cutting faults in relation to the bay are identifiable.

Three dikes, one of which strikes between W. 40° W. and W. 40° W., cut through the lava in 600 feet across the coast at the head of the bay. The first dike is 6 feet across, but 25 and 27 feet long in width. Many are flat and strike the fault shown in Plate 1, inset B, at the head of the bay, has a downslope of 3 feet to the south. The 6-foot dike striking west has faulted back on itself, and a 6-foot parallel dike near it is faulted in the middle, indicating possibly a fault system. Displacements could not be measured.

Some eight dikes and several faults are exposed in the west shore of the bay. The first dikes are as follows: where there is a 5-foot, 55 between 2 and 5 feet, and 6 between 5 and 6 feet. Most of them trend nearly east-west. The dikes are too numerous to be numbered near the promontory at the entrance of the bay, partly because the rocks are stratigraphically close to the original surface of the volcano. A few tentatively described.

The main fault zone is half way to the point of the promontory. Seven dikes, nor faulted or bordered by 6 inches to 2 feet of fault scarp, were noted between valley and the promontory. These faults are in addition to those listed in the 7, 12, 13, 14, 15, 16, 17, and 18.

Shear dikes of horizontally bedded pale brown vitric tuff, 4 to 6 inches wide, within a plane, have faulted 18 inches thick, westward on the shore (fig. 3). An additional faulting, where blocks of ash and other debris 60 feet long, have faulted back on itself, and a 6-foot parallel dike near it is faulted in the middle, indicating possibly a fault system. Displacements could not be measured.

Some eight dikes and several faults are exposed in the west shore of the bay. The first dikes are as follows: where there is a 5-foot, 55 between 2 and 5 feet, and 6 between 5 and 6 feet. Most of them trend nearly east-west. The dikes are too numerous to be numbered near the promontory at the entrance of the bay, partly because the rocks are stratigraphically close to the original surface of the volcano. A few tentatively described.

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Thirty dikes, mostly less than 0.5 feet wide, are exposed on the northeast side of Pago Bay. A few probably are the continuation of dikes already described sticking out onto the opposite shore. The dikes cut thin-bedded primitive rock to a depth of about four feet in thickness (Pl. 6, fig. 1). An obvious Tab. 1.—Ridge faults on the east side of Pago Bay

<table>
<thead>
<tr>
<th>No.</th>
<th>Struck</th>
<th>Dip</th>
<th>Strike</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>N. 30° E.</td>
<td>60° NW.</td>
<td>30° N.</td>
<td>Bound by 2 feet of basalt.</td>
</tr>
<tr>
<td>2</td>
<td>N. 40° E.</td>
<td>50° NW.</td>
<td>40° N.</td>
<td>Bound by 2 feet of basalt.</td>
</tr>
</tbody>
</table>
| 3   | N. 35° E. | 50° NW. | 35° N. | Drowned apparently small.
| 4   | N. 30° E. | 60° NW. | 30° N. | Cliffs at front head of yellow soil talus. |
| 5   | N. 30° E. | 50° NW. | 30° N. | Associated with fault 4. |
| 6   | N. 40° E. | 60° NW. | 40° N. | Associated with fault 4. |
| 7   | N. 35° W. | 60° NW. | 35° N. | 100 feet from fault 6, drowned to 70° N. |
| 8   | N. 45° E. | 60° NW. | 45° N. | Drowned.
| 9   | N. 45° E. | 50° NW. | 45° N. | Drowned by 6 inches of basalt. |
| 10  | N. 30° N. | 60° W. | 30° N. | Drowned in sandstone. |
| 11  | N. 35° W. | 50° S. | 35° N. | Faults 11 and 13 bound a block 25 feet thick. |
| 12  | N. 30° W. | 60° N. | 30° N. | Fault with breccia (Pl. 2, fig. 3). |
| 13  | N. 30° W. | 50° N. | 30° N. | West side of beach.: |
| 14  | N. 30° W. | 60° N. | 30° N. | Drowned by yellow soil talus. |

These dikes are formed beyond the village, striking N. 30° W. and 0.5 feet wide, in unconsolidated sand. The core consists of fine-grained sandstone oriented with their vertical axes parallel to the sides of the dikes and with their larger and heavier parts downward (Fig. 4). It seems that their concentration is due to the weathering in the liquid at the base of the eruption. Dikes with scattered sandstones are common in Tutuila, but two were found in which sandstones were concentrated. The concentration of these sandstones was taken place 500 ft or less below the surface. Dikes and their track find of breccia were noticed. The breccia beds are N. 30° W. and 30° N. and are 13 and 25 feet wide respectively. The sample is a downdrag of thin-bedded fault with two intercalated vitreous 1 ft thick. Just east of the breccia lies a dense columnar-jointed 2500 ft thick. It is probably locally thickened by compaction in a faulted rock, but the fractures are not discernible in this section of thin-bedded breccia.

Breccia is a type of tuff containing mostly between N. 30° E. and 30° W. and 2 and 3 faults are exposed on the western shore of Alama Bay. The whole area of the village is a steeply faulted with a large polygonal compound, 40 feet wide, that is 15 ft wide, and with 2 and 3 feet wide respectively. The rocks forming the upper side of the dike are N. 60° E., and dip 30° N. At the base of the breccia, the breccia are abundant. The dike is 18 inches wide, strikes N. 40° E., and dip 80° N. Phyrhic suite containing angles and older breccia are abundant. The dike is 18 inches wide, strikes N. 40° E., and dip 80° N. The breccia is fine-grained, probably means that it is not far below the level at which the lava erupted.
The dike is split by a fault striking N. 70° W. and dipping 82° S. The west side is downthrown 3 feet. The breccia bed is also exposed on the west side of Cape Point.

About 1000 feet southwest of the point an aphotic dike contains in its vertical band of explosion breccia 3 feet wide and a fragment of dike rock 6 feet (Fig. 3). The dike strikes N. 35° E. After the dike congealed, apparently peeled it apart to form an orangie crack at the surface point to the explosion that the breccia. The same dike further southwest has a 8-foot vertical core breccia. The cracks typically filled in the crack...features were filled, in Origins, an Kiholo Volcano, Hawaii, in historic time. About 100 feet to the west is a massive bed of basalt that probably congealed at a depth unknown to a 6 feet of subside.

Some of the breccia interbedded with the basalt in the small key west of the signal to be explosive islands that rolled or washed down a steep slope ground to the bed and put up the deck. On the west side of this bay is a partly fresh dike with 30 feet at its foot dipping 25° SW. The downthrow is to 52 feet at the shore.

The whole series of lava, tuff, and breccia beds on the west side of AHO grew to be plunging over the buried unstability bounding the north of Markus dike complex, but additional field work is necessary to establish the AHP road cut into the west wall of Mounts Valley in 1911 exposed.
The 50-foot-dike strikes N. 40° E. and cuts off a cliff at an altitude of 25 feet, thence northward where Mounta Peak. A 2,000-foot-long island extends in a north-south direction across the entrance to a harbor of 500 feet. The island is the easternmost point on the north shore of Yvans Point.
Others, aggregating 10 feet, are silty, limonitic, and rich in fossil plants. The tops of the roll changes abruptly northward to N. 60° E., and the dip to 30° S.E., rapid changes in strike and dip are probably due to the Pago faults meeting a vein of the caldera wall.

At an altitude of 920 feet on the northeast side of Tapo Park a vehicle flow 13 feet thick fills a gully cut in cinder beds but separated from them by a 25-foot shift of coarse talcoselaminae hillwash and slightly weathered breccia. The rues N. 20° W. and dips 45° NE. The thick cinder beds under Tapo indicate that this area was previously along the caldera fracture bounding cinder cone at times cascading down the wall of the caldera. The hillwash indicates a erosion. period.

The rocks of the Pago volcanic series east of Tapo Park are unerupted and thin by massive ponded lavas. The track from Fagan to Ioosuapapa passes to a saddle on the north side of Tapo. Thin-beded primitive lavas and easterly end fault cut out along this track from Fagan to the saddle. Very common breccia cut out along the track from the saddle to Ioosuapapa as the south of Tapo Park. The unconformity is exposed in the east contact of the caldera in Ioosuapapa Valley west of the track. The exhumed caldera wall of thin-beded primitive lavas cut out by many closely spaced vertical striking S. 10° W. The wall strikes N. 60° E. and dips 30° S.E. It is open conformably by 30 feet of poorly bedded talus and explosive breccia. A dike complex cut out in the valley on the northwest side of Tapo Park of 125 feet (barometer). Above this point massive lavas crop out, dike complex abruptly disappears. This apparently indicates an unerupted caldera wall between the caldera-filling lavas and the dike complex.

The rocks in Tapo Park are thin-beded cinderaceous lavas with occasional

"Tupula (American Samoa)"

that appear to be extra-caldera lavas. It is inferred that a secondary caldera lies on the north side of Tapo Peak and that the main caldera fault passed through Opana Valley because of the extraordinarily large size of the valley (Pl. 1), leaving a break in the north wall of Opana Bay between Tapo and the head of Opana Valley. The line of the caldera fault is indicated by open-crested stream channels on the west side of Tapo (Pl. 2). Probably sufficient water exists to fill the caldera, but the exact location of the caldera is not certain. The fault between Pago and Fails Falei Peak may be a part of the Pago Fault, and the section on the east side of Bridge Point is as follows:

<table>
<thead>
<tr>
<th>Depth (feet)</th>
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<tbody>
<tr>
<td>6</td>
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<tr>
<td>12</td>
</tr>
</tbody>
</table>

Note: The section clearly indicates a gap between the late intra-caldera lavas flows at the north end cut out of lavas at an altitude of 125 feet in the west flank of Natou Stream at the village near Falei.

"Paga Calcareous"}

These given shows that a great angular unconformity separates the lavas in the area between Tapo and Pago Pago Valley from those in the rest of the island. Evidence pointing to the caldera forming by collapse of the caldera wall and the holding of a cone of primitive lavas is the complex faulting at the contact of the caldera wall and the caldera.
located by 22 feet of friction breccia containing fractured blocks up to 2 feet thick. The average has been so great that waves of the similar fragments have been large enough to smooth both resembling water-worn pebbles. Fifty feet east a rounded pumice

a foot thick due north and east, and dipping NNE. It is bordered by a zone of pumice

a closer zone 3 feet wide.

The lava inside and outside the caldera differ, indicating that the collapse was

1600 feet. The original summit, found on the projection of the slope in the

caldera, would have risen about 3000 feet above sea level if it had the same slope to its apex. Thus, the amount of collapse of the summit has amounted to 4000 feet. The southern rim of the caldera was evidently

lower than the northern rim. The caldera may have been horseshoe-shaped with

rim on the south. By analogy with other similar lavas in the area, it is

probably preserved with the growth of the upland part of the cone, the caldera

shrinkage, and deepening progressively even though lavas were erupted simultaneously

to form a caldera. Outcrops finally stopped as the volcano approached old age and

lavas began to differentiate. Filling gained on the caldera, and at the central activity the caldera was filled with 600 feet of lava in the southern and southeastern part, but never about 600 feet of being filled in the southwestern sector (PI. 4). Linear lavas are subdivided, the Pago Volcano passed through the four phases of volcanic activity observed in Hawaii (Strom, 1944), p. 1947: (1) youthful stage with

eruption of the primitive shoshonic lavas, (2) mature stage with collapse forming

calderas on the summit, (3) subaerial stage with differentiation of the lavas and

filling of the calderas, and (4) representational stage with eruption of basaltic rocks.

Great eruption (1906).

TRACHYITE PLUGS

General statement.—The trachyite plugs in Tutuila, are the feeding plugs of basaltic domes. Some plugs, such as Vaiava and Pago, are too small to find parts of the relief of lava, they are transitional between lava and domes. Others have lost their flat surface by erosion and are true plugs.

Pago plug—Vaiava, “the tile maker,” is a trachyite near 3000 feet high. This is the largest trachyite near the summit. It is 1200 feet long and 11 feet wide. Only has described it as a

phallic lava with a well defined cone and a large lava flow from the cone. The Maar is 300 feet in diameter and has a small crater.

On the edge at the base of South Pago Peak is a magnificent and very

beautiful lava flow. It lies at an altitude of 900 feet by the crossroad near

the top of South Pago Peak. The Puu Pukao saddle is below the base of South Pago Peak. It may walk along 1500 feet at this level of this lava, which is broadened into a thick plate of lava.

The area around it is a series of small mountains and plateaus. The lava flows are well preserved and form an appreciable part of the thick mass of lava at the head of the Valley. Some portions may have washed later.
from the slope of the Pua cone before the caldera was topped by the ancestral Pago Scoria.

![Diagram of Pua and surrounding landscape]

**Figure 5—Steps in the formation of Pua Peak, Tutuila**

**Pua scoria plug** — The Pua scoria plug of trachyte is about 1000 feet long, 5 feet at the top, and 200 feet wide at the bottom. It lifts a sharp windward slope high with precipices with respect to the northern end where it can be ascended by clinging to roots and heavy moss. The rock is vertically jointed and columnar.
beds and have flooded them. The lavas have interbedded with these tephras and breccias of the Pago volcano series, chiefly basaltic, but containing trachytic fragments.

The Maolua plug is cut by parallel joints which give it a foliated structure, as exposed in the Pago Reservoir wall. There the joints strike N. 80° E. and dip N. 65° W.; along it is 400 feet. The northwestern side is domed, with a slope of about 2°. A large volume of material is exposed at the point, and a large amount of material is produced by the weathering of the lavas of the plug. The lavas of the plug are basaltic and trachytic, and are cut by parallel joints which give it a foliated structure, as exposed in the Pago Reservoir wall. There the joints strike N. 80° E. and dip N. 65° W.; along it is 400 feet. The northwestern side is domed, with a slope of about 2°.

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chordal marine phenomenon because of these lakes at tide level. Tide levels of the
lakes are exposed near Sp. Remnants of seven crater fill and cinder cones are ex-
plored in the cliffs along the north coast and about the same number on the south
coast. A pit crater filled with breccia and the partly buried sector of a cinder cone
with later breccia blanked against it are exposed at Greenbush Point (Fig. 10). A

**Figure 10** — Sections of pit crater and partly buried cinder cone near Greenbush Point, Tutuila.

beach of billecho, none more than 10 feet thick, are intercalated with the lava,
and 10 feet thick breccia was found. The breccia cut near Greenbush Point and below
steep slope, possibly a cinder cone or cliff not far away.

Several log mounds are in the lagoon overlying a thin vitric tuff bed in the ge-
ometry west of Uepi indicating that vegetation grew on the volcano during sea-
phase.

The Tapatapu Volcano is separated from the Pago Volcano on the basis of the
lava beds exposed in the steep slopes into Matseha Bay. No unconformity
found between the lavas of the two volcanoes, but from the geochronology of the
lavas of Tapatapu Volcano overlap those of the Pago Volcano, hence are younger.
The relatively small amount of distinction of Tapatapu and the Pago Volcano supports the hypothesis that the younger

**GEOL MATCHES**

The Leone volcanics consist of three tuff cones at Stepa Point—Trigume, (P1, 6, 6, 3), and Vahuran; the sandy ash at Fugia, two cinder cones Maupapaga; and the palaeo-sediments blank the plain between Etagon and Leone. The top of the palaeo-cones at Leone Point is about 6 feet
sea level. A collapsed lava tube in its surface is bounded by delicate hornfels.
Fire-ground tuff is packed into the cavities in the spatter showing the tuff fall after the lava flows had solidified and collapsed. On the lava flow, a spatter to half an inch thick, are typical fragile cinder-like tuff.
Above them lies 1 to 2 feet of sandy lamination vitric tuff. The
plains does not seem distant from its source. Coarse powdered explosive

**Figure 10** — Sections of pit crater and partly buried cinder cone near Greenbush Point, Tutuila.

feet thick rests on the sandy tuff. Above the breccia is 6 feet of thin-beded,
sub-angular vitric sand tuff a mile or more from its source. The breccia bed
thick 1000 feet unsolidified. The larger spatter cones are not covered with except for
the larger cones. A hill of about 125 feet high with a depression in its summit lies just southeasterly of the lower tuff consolidated
by a local explosion west named Vaialata from the village on its sea side. Prob-
able cause was caused by the lava flow exploding in contact with sea water, as the

**TUTUILA (AMERICAN SAMOA)**

The thin-beded tuff above the breccia is not found at Vaialata, as it is
seen eastward to Stepa Point. At the hillside about 14 miles southeast of the
Point, 20 feet of horizontal thin-beded tuff is exposed. It is overlain by a
recently slightly weathered tuff. On this tuff and lower tuff is 20 feet
above the thin-beded tuff which fills stream channels cut after the lower tuff consolidated.

The lower tuff is probably from Fugia Crater, and the upper from
the crater. The relation could be determined by a least traverse of the coast, the
randomly deflected spatter cones in the lower tuff near the hillside that
seen on the present produced cone in the tuff by wave erosion. One gets the im-
pression that the topographic similar to the present one had been developed in the
tuff prior to the eruption of the upper tuff. The

1. They thin out rapidly eastward, but small patches were found in depress-

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50. 6 feet thick: 6 to 8 feet thick: 6 to 8 feet thick:
also, filling it as far as the present site of Tucumcari 3 miles away. The standing water causes the lava to overflow and rework the basaltic debris along the west margin. The lava is 200 to 300 feet thick at the water edge. Some lava probably flowed over the outer edge of the Tucumcari basalt.

Faganacon consists of three separate parts. The main part is the Tucumcari basalt. Fifty feet of paler basaltic rock, 15 feet of metapelite, and 3 feet of banded basalt.

The lava is 1000 feet long and 200 feet wide.

Faganacon is named after the town of Fagana, a small village in New Mexico.

Tucumcari (American Indian) is a town located in the Tucumcari Mountains.

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Faganacon consists of three separate parts. The main part is the Tucumcari basalt. Fifty feet of paler basaltic rock, 15 feet of metapelite, and 3 feet of banded basalt.

The lava is 1000 feet long and 200 feet wide.

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reef as it needed but leaving island unconsolidated beach deposits, sea cliffs, and caves.

**Geomorphicology**

Tutuila with its rugged terrain and deeply embayed coastline is evident of a long history of stream incision followed by subsequent (P. Id.). The extensive recent day plans between Nuuuli and Leane isla are built of terraced lava and tuff indicating an eroded barrier reef. Actually Tutuila is far more rugged than the contour Plate I indicates as they are much generalized. The river valleys are narrow and deep, and amphibolite breaks in the coastal basaltic island. The steady stream cut across the one hundred feet level cut occasionally. Probably as much as 200 feet of rain falls on the high coast in one year. Streams are flashy; but erosion is rapid during droughts. Landslides occur by the hundreds during hurricanes. The faces of the high peaks are covered with trees. Even light winds on rainy days blow down large trees which start landslides. The effectiveness of this process for leveling islands with extremely ruggedly is evident of the stream course. The river valleys in August 1941 were still altered largely from the hurricane of 1940.

A systematic geomorphic description of the island from east to west includes:

**Anamau Island**

Anamau Island is a recent tuff cone built on top of the covered barrier reef, prevailing southeast trade winds sweeping around the island have built a western side-a broad flat of coral sand a few feet above.

**Cape Mal战略**

A three columned-jointed basaltic neck which rises from the sea level. The former course is now covered with sand and vegetation.

**All drainage radiates from Ouinao, the highest peak of the Ouinao Valley.**

The narrow neck of land between Anau and Anamau results from the narrow saddle between Ouinao and Malaea by the draining of two large craters. The craters are especially large because each carried the drainage from the head of two valleys instead of one. Fagafouta Bay, the second largest bay, is unusual size to the draining of the walled caldera of Malaea Volcano (P. Id.). Fagafouta westward near is Pala Pala. All major streams flow directly south of the original course of Malaea plug, but the canyon was not examined.

**Leane Lava**

Lava flows from sea to a stream which entered inland along the rim of the Pago Valley and somewhat as in Pago Pago Stream did. Lava flows from sea to stream as it sinks into the highly permeable Leane that drains the north coast of the valley.

**Geologic History**

The geologic history of Tutuila started when the rift opened on the floor of the sea and the first lava erupted about 15,000 feet below the surface of the ocean, in the Eocene Tertiary time. The island is the top of a volcanic pile about 3 miles site of Pau Pau cone. This cone also caused the Anau tributary to cut the caldera wall on the southwestern side of the cone. Thus Pago Pago Bay is a drowned valley, which owes its unusual size to the large drainage area, weak streams in its floor, and high caldera wall on its north side.
of the eroding banks. They were spread so evenly as though they were the rocky side of a great cliff block.

Pyroclastic fans are notably steeper than cones composed of lava flows. Rapid initial erosion by wind and water probably removed the layer of sediment produced by the explosion of the lava when it encounters water. But the initial flow from the vent was around 127 to 227 °C, sufficiently to form the sheet of splashing water. The history of Tahiti after it reached the sea follows:

**Fissure Zone (August 31)**

1. Outpouring of primitive olivine basalt from rift zone extending N. 30° between the posterior part of Aho and Manamoa bays followed by cinder cone forming on the surface, producing the Manamoa cone complex and an associated rift vent.

2. Outpouring of primitive basalt from three separate fissures 3 miles apart extending N. 80° E. and the development of the Manamoa, Paga, Aho, and Aho Naka vents with sheeted lava domes.


4. Development of the underlying magma reservoirs or craters leading to the formation of pahoehoe lava and spatter cone types of lava (cf. 5).

5. The southern rim of the Paga caldera was apparently buried by these lava flows with subsequent explosions accompanied by steam and hot-water vents in the Paga caldera. Steam and gas escaped between June 21 and 27.

**Early to Middle (2) Fissure Zone Time**

2. V-shaped stream and various narrow canyons carved deep canyons and wide plateaus (Fig. 3, page 2). The terrestrial debris carried in the streams formed a volcanic ash.

3. Apparently formed during the waning stage of the eruption when the lake was rising due to the volcanic lake forming in the Pakea and deep canyons in the caldera-digging lava that sunk in the foot of the wall of the caldera. The lava flow cut into the caldera floor and deep canyons in the caldera-digging lava that sunk in the foot of the wall of the caldera. The lake has since been exhausted by the steam escape of water and by water leakage along the edges of the lake bed and through the walls of the caldera.

4. Subsidence of 600 feet possibly 2000 feet carrying down the entire marine shell with its rocks, simultaneously forming the valley and allowing the water to attack the entire area. Continued rapid alternation of valleys was the result.

**Middle to Late Fissure Zone Time**

2. Rapidly fluctuating ice level in response to changes in the volume of the ice cap and concurrent changes in the configuration of the action function.
glacial periods and rising sea level coral reefs flourished only to be killed and come about by the waters of the sea fall, in glacial times. During late Pliocene and early Pleistocene, probably founded on a lowered barrier reef of the previous interglacial, and eroded Turtles (Pl. 5, stage 4).

A rapid subsidence of about 200 feet, drowning the barrier reef, although a few cobbles of it are seen at the rising sea level until it reached within about 50 feet of present sea level. Continued subsidence of the valley mouths.

Emergence at 20 feet leaving large sea caves above sea level last 19 marine beds. The sea eventually became occupied by the tall fleshy encrusting algae as is left.

**Recent Time**

Emergence of the Leone volcanics from a north-south fissure 3 miles long forming cones where the lava erupted over lava and cinder cones on the land. The lavas were partially scoured on the submerged barrier reef and added about 8 feet of land to Turtles. A shallow submarine explosion formed Anjouan Island northeast of fleshy encrusting algae continued.

Further emergence of 2 feet leaving lavas up to 32 feet high on the Leone volcanic, small remnants of encrusting reefs, and lava at the mouth of the major valley (Pl. 5, stage 3).

**Manini Group LEMURIAN SAMPLES**

| Islands of Obo, Olona, and Tusi, together with the several that make up the Manini group, are peaks on the top of a great volcanic pile 80 miles across, formed from the Turtles pile by water 2 mile deep (Fig. 16). They are built on a rimming N. 30° W., which comes down the northeastern edge of Tusi through the line of Olona and through the west end of Obo. A submarine eruption occurred at southeast of Olona on the areas of 1866 (Fig. 11).

**Obo and Olona**

Obo island.—Obo and Olona are remnants of a single basaltic volcano about 4 miles wide from north to south and 8 miles long from east to west. Noted that the volcano was a typical basaltic cone of the explosive type. The lava does not appear to be a flow, but rather a mantle of basaltic type, but it may have been a lava flow. The volcanic rock is not so numerous as around the main area of many basaltic volcanoes. The structure of the cone is very unlike a Marionian cone. It is, off the west side of Obo, a distinct basaltic tuff cone. The basalt cone is a very rich area in basaltic volcanism, older cinder, and post-caldera volcanism, probably dating from an early period (Fig. 55).

**Shoreline volcanoes**—The post-caldera volcanoes consist of spatter cones and the south sides of Obo. They consist chiefly of thin-bedded lava flows but also of the caldera 20° to 20° with lesser amounts of pyroclastics, chiefly...
was not visual. Just west of the south tip of OIa-tu there is a series of long stone walls, each with a notable cordon-stone, coiled near the base of the cliffs.

The harbor is a complex of several inlets, with the Shallow Trough of OIa-tu and the northern and southern ends of OIa-tu.

The area around the north end of OIa-tu is the easternmost point of OIa-tu, near the southeastern tip of OIa-tu, which projects under the influence of mariner erosion at Fowlecliff.

Some of the cliffs are broken by the many channels, which are often narrow and deep. They vary in depth from 10 to 20 feet, with a maximum of 30 feet, and are often divided into several channels by small headlands.

The cliffs are very steep, with a maximum height of 200 feet. They are often divided into several channels by small headlands.

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The island is built over a rift trending N. 30° W. Potentially another rift, once N. 30° W, now possibly more deeply cut, trends W. A half-painted eye, a few short linear cracks (Fig. 12). The axis of this rift is with the western end, hence can contribute little. Throughout proposed the rift cut high cliffs to the south side were fault scarp of a large volcano. The topography here substantially such a volcanic, but the present remnants of few cliffs probably not the fault origin as the one on the north side of the rift, a trend of small-dike lava took to the descending block. It is even mapped as such in Figure 11 although it may be partly venturized with lava quay lavas. The 2000-foot cliffs on the north side are due to erosion, perhaps in contact with another caldera. It is smoothed as through venturized with lava.

The southern slope is a semi-eroded rift area. Here noted that the outer covering of the island is built for forest with cortex that partially neutral (Fig. 12). The surface of lavas at the top 10 feet are peperifur (olivine-drague) basalt similar to the Figure 12. They are filled with gorgous. One massive sheet stands up above along the spine of Orientals of Tolimans are pumiceous. The outer pumiceous half is deeply to the blood so we are asked to make a nearly 4 mile wide and 1000 feet high, starting at the 5000 feet. It is probably correlated with the submarine block around the other volcanic islands in the Southern group.

Geological data on which to base any test very tentative conclusion are:

1. Building of a basaltic cone 5 miles wide and 1000 feet high in Plinocene time over a rift trending N. 30° W.
2. Collapse of the summit to form a caldera 8 miles across on its north slope.
3. Long period of eruptive stream activity and formation of a broad coastal shelf by deposition and wave erosion.
4. Subaqueous of 400 feet at some.
5. Removed volcanic exposure in late Plinocene and Recent time that much of the summits are fresh lava flows and breached pumice caves. Tang to the downwearing off the northeast shore exposed and built till.
6. An emergent at 2 feet, leaving a raising bench materially preserved by emergence.

Note:
Some Island is a coral cliff with sand beaches 10 feet above sea level, partly built on a volcanic basement in late Plinocene time. Erosion might indicate a 3-foot drop in sea level (Plinian, 1219, 1-75).

SOUTH EASTERN SHORES

Sugar is built over a main rift cone that trends S. 90° E. towards the rift from a line of eight cataracts which divides on the northeast side and...
Using S. 70° E. to Cape Tupulagi and the other S. 50° E. toward Upolu Island, we left the two chains of islands farther south on Savaii, and off the coast lies a subaqueous reef 9000 feet across. Apparently the two chains of islands sheltered the covering sea from late lava floods. Another rift zone marked by cones runs N. 15° E. across the Small group. This zone started sometime after 1911. The lava covered a barrier reef and ran long-distance onto the outer reef of the former island, forming a new barrier reef, and covered the low-lying islands eastward from it.

The lava flow is by no means uniform. The lava flows are frequently divided into several smaller flows, and the direction of the flow changes frequently. The lava flows are generally directed towards the sea, often forming new barrier reefs. The lava flow is also influenced by the topography of the island, with the lava flowing down valleys and into valleys.

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fault scars bordering block outwash to the east rather than by having canyon walls.

A barrier reef 14 to 2 miles across extends for 14 miles along the northeast side opposite Upolu. Its lagoon, 10 to 66 feet deep, is separated from the sea by a fringing reef half a mile wide. Both ends of the barrier reef are bounded on lagoon sides by low islands. 'Uta'a Savai'i, a cone 633 feet high, permits a view of lagoon which extends 14 miles southeast over the barrier reef toward Apolima Island. A second and less in the broad bay on the west side of the flat. Nearly all the east coast of Savai'i is reefless, and much of it is rock bound. However, a line of islands indicates a submarine shelf 3 to 12 miles wide and less than 100 fathoms deep completely surrounding the island. Other lagoon shores that have passed have been directly into the deep Pacific have dips of 10' to 25' along the shore. The shelf South of the Quaternary lave covering the dome have buried a local boost near the shore; perhaps causes a barrier reef. This drowned lave-covered shelf is connected with the drowned barrier reef and surf terrace Upolu. The larger evidence at hand supports the hypothesis that Upolu and Savai'i have had parallel histories except that Savai'i produced more lava in the late Quaternary.

UPOLU (SOUTH SAMOA)

GEOMORPHIC CHARACTERS AND AGE OF THE ROCKS

The form of Upolu is seen from Aiga Harbor is shown in Plate 8. The island composed chiefly of basaltic rocks, lava flows and their feeding dikes, and terrestrial diatomaceous marls or clays.

Quaternary formation

Pliocene formation

Miocene and late Pliocene formation

Great reversed geologic

Pliocene and earliest Pliocene formation

Sedimentary rocks unclassified

Fracture

Lava flows and their eolian breccias and cinder cones

Extinct flows, lave flows, and their eolian breccias and cinder cones

Basalt, dikes, and lave flows

Fracture

Dip analysis

Excluding the lave flows in the area designated in Plate 8.

Dip analysis

Great reversed geologic

Dip analysis

Dip analysis

These rocks are mostly composed of basaltic rock, breccias, rhyolite, and andesite.

The general age of the Puna volcanic system in eastern Upolu is given in Plate 8 from 8 to 25 million years ago. This rock is mostly composed of basaltic and andesitic rocks, and andesite and basaltic andesite.

The Puna volcanic system in eastern Upolu is mostly composed of basaltic and andesitic rocks, and andesite and basaltic andesite.
The lavas are chiefly olive basalt. They appear to be primitive lavas and support the building of a new volcano. Pulchour flows are common. (See McCauley, 1943.) The lavas are almost horizontal near the coast and dip about 10° to the crest. Some are very massive and doleritic jointed where they congested over-elevated canyons. They were spread over the deeply eroded Pliocene rocks and which filled deep basins. Some lavas are intruded by 30 feet or more thick, representing older canyons cut in the Pliocene lavas and partly filled with breccia. Such terraces are well exposed in the valley draining to Aipa.

The lava flows of the island opposite Aipa are cut by canyons 300 feet or more deep. One gains the impression that the bulk of the Pliocene lava or was erupted in a single period of intense volcanic activity, followed by a resumption interval interrupted occasionally by Recent lava flows. However, detailed work reveals that there are many proximal unconformities in the Pliocene lavas and that these canyons resulted either from topographic thinning of flows or from localization of outflows, rather than from one major eruption.

The greatest bulk of the Pliocene lavas was erupted in the late stage along the crest between Mt. Vunafo and Mt. Tikitidua. It is suspected that this stretch is the result of a single period of activity or summit zone of the Pliocene volcano. Tula support, explored by Esau, it is the Pliocene cinder cone with a crater 300 feet deep that erupted on the summit of a Pliocene eruption. It was not flooded by the water, but apparently most of the lava from this crater flowed westward and then northward. The great volume of Pliocene lavas extruded in this area extended the former north and south shores of the island about 3 miles. Geologic outcrops indicate that the lavas extended the pre-existing submarine all 3 to 5 miles as shown by the bathymetric in the 100-foot line (Fig. 13).

Kanoa island is a Pliocene lava cone surrounded by a volcanic barrier reef.

RECENT VOLCANIC

The deposits lavas and associated cones range from a few hundred to several thousand years old. These lava flows are shown in Figure 13, but probably others.

The three lavas mentioned are from the top of the sea with heavy tropical rains and the near-shore lavas. The lavas with historic lavas in similar climates where they cannot be more than a few hundred years old. They will be named, for instance, the Litidi flow, the Sungo flow, and the Lefaga flow.

The Lauili flow is a very fresh, clastic lavas on the north side of the island and in unknown locations (noted by Esau, 1949, p. 246). Large trees grow on its slope, but between them are bare hauhinah black, rocky pockets typical of a recent flow.

The Litidi flow fills a valley cut in the Pliocene rocks. It is nearly at the summit, but its source is probably not the crest of the range to the south. The lava is probably the youngest of the three lavas erupted.

LiThai flow is an olivine basalt as flow more than 20 feet thick. It plasters
the floor of the stream after which it is named. The flow was traversed at 54 t of the Fale-o-ta-fae, about 150 feet altitude, but it comes apparently from the top of the ridge. The streams, which flow at the rate of 10,000,000 gallons a day, at times probably 50,000,000 gallons a day, have scarcely removed the surface. Although well marked by vegetation, the cliff is free from soil and humus on both sides of the stream tail.

The Lefaga flow is an active basalt phreatophobe flow that followed the course of the Lefaga River to the coast. Only in a few places has the river cut through the crest. The source of the lava is unknown. It partly filled the gorge of the Lefaga River that was cut along the contact of the Pleistocene and Penepluvial lavas.

The lack of red ash along the coast between Samoan and Tofaafa lavas probably indicates a great fan of Recent lavas. It may be the recent lava noted by Davis (444) at Sinepu, a town cut on maps available to the writer. Unmapped old flows of Recent age appear to be transitional into the Penepluvial lavas.

Apulima Island was studied from a plane. It is a Recent subaerial upland which is a submarine explosion, 100 to 150 feet high, rising in the shallow Apulima Strait. It is a small volcanic island without a seam.

Several tuff cones form a rim off the coast and the island. They were not visited, but they appear from published descriptions to be subaerial in their upper parts. They were apparently cauldrons rising on the main rift and explosing in shallow water. They are probably few Pleistocene or Recent as indicated by the pumice on their rad.

Living Reefs

The living reefs of Upolu are readily separable into fringing and barrier reefs (13). The fringing reefs range from narrow shelves to 12 miles wide. They are composed of corals, sand, and shells, and other detritus with coral boulders bound together with calcareous algae at the outer edge. They are near the sea at low tide (fig. 1, 13). There is no shoreline by a barrier reef for nearly along the south coast.

The main barrier reef is nearly continuous from Vailele Bay all the way along north coast to the east tip reef along the north coast to the spot of rocks forming the west side of Lefaga Bay. Shorter barrier reefs at the west and along parts of the south coast, also. A barrier reef is missing along most south shore, possibly because of island a bulk of food supply for coral reefs by other hydrographic conditions, on the formation of the coast by very late. This barrier of the coast was not traversed beyond Lefaga Bay, but in that area the barrier is too young to support a barrier reef.

A barrier, 2 to 6 fathoms deep, separates the barrier from the fringing reef at east. The barrier reef lies 1 to 3 miles offshore. The seaward side of the drop at a depth of 10 to 20 fathoms, where it exceeds a submarine to 3 miles wide and 30 to 50 fathoms before sea level. The outer edge of the drop at a depth of 100 fathoms and still more abruptly to 300 fathoms and ceases between Upolu and Savaii where the shelf has a gentle slope from 40 fathoms. Soundings are longer extreme along the northeast end of Upolu, but are insufficient to determine the submarine contour lines approximately as Figure 13.
The eruption period was followed by an eruptive activity along the eastern coast. Volcanic debris, in the form of ash and pumice, covered the area with a thick layer. The lava flows extended along the western coast, forming new landmasses.

The area is characterized by a combination of volcanic and erosional forces, resulting in a diverse landscape. The beaches are composed of volcanic ash and pumice, while the interior is covered with lava flows.

To understand the geology of the island, it is important to study the eruptive history and the effects of tectonic activity. The island is still an active volcano, with regular eruptions occurring.

The coastal erosion is a significant concern, as it affects the local ecosystem and the infrastructure. protective measures are necessary to mitigate the impact of erosion.
aby two pits mangroves; (2) Tutuila; (3) Manu group; and (4) Rana Island, occupying 2 to 3 miles deep between them.  

Their major history above sea level is remarkably similar:  

**Pleistocene or Lowest Pleistocene Time**  

(1) Period of rapid extension of primitive edifice basaltic building the seamount volcanoes.  

(2) Collapse of the summit of man of the volcanoes to form calderas.  

(3) Continued lava eruption partly filling the calderas. The rate of eruption appeared all with the production of more symmetrical domes and more of less differentiated flows and peperaline.  

(4) Tuffic lavas, the end phase of differentiation, Pacitic basaltic volcanoes, were erupted on Tutuila and probably at one place on Upolu.  

**Early and Middle Pleistocene Time**  

(1) Continued eruption throughout the archipelago.  

(2) Long period of steam and minor eruption forming cliffs, platforms, and peperaline.  

(3) Salination of at least 100 feet and perhaps as much as 2000 feet with sand and alluvial plains as examples as of previously built submarine platforms.  

(4) Continued saltwater intrusion (as) barrier reefs to grow during interglacial periods and to be either partly or completely destroyed during glacial periods.  

(5) Fluctuating sea level causing barrier reefs to grow during interglacial periods and to be either partly or completely destroyed during glacial periods.  

(6) Continued growth of the islands during the last 20,000 years as the sea level has fluctuated.  

**Later Pleistocene Time**  

(10) Continued volcanic activity on Savai'i and Upolu, and probably on the various stretches of reef.  

(11) Continued eruption of the lavas has continued since this eruption, and terrains where the land was last continually covered with lava.  

(12) Salination of about 2000 feet, destroying the previously formed barrier reefs, perhaps due to the decrease in the level of water from the melting ice caps of the last age.  

(13) The coconut palms and the previous barrier reefs are covered by the upraised and forested barrier reefs off Upolu and parts of Savai'i last raised up on the steeper slopes composed of Pleistocene rocks.  

(14) Emergence of 20 feet having numerous abandoned sea caves.  

**Recent Time**  

(15) Continued volcanism, this time forming numerous offshore and coral reefs, is seen all islands except Upolu.  

Some of the lava flows have partly filled the streams of rising reefs.  

**Geologic History of Samoan Islands**

- Emergence of $5$ feet leaving abandoned sea cliffs, stacks, caves, and loose sediments.  

**Historic Time**  

(16) Continued volcanism with a submarine eruption between Tau and Gorea at $300$ and several eruptions on the island of Savai'i, the last ending in 1931.  

**References Cited**  

(1)읶 (1927) 'Oral rehs from Western Samoa, N. Z. Inst., Vol. 52, pp. 231-264.  


