55. *On Some Pebbles collected from the Floor of the Japan Sea.*

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Introduction.

In sounding the Japan Sea, a surveying ship of the Hydrographic Department of the Imperial Japanese Navy collected in August, 1931, at 39°50′ N., 133°50′ E., a granite pebble from the sea-floor at a depth of 453 m. This is in the northern part of a submarine ridge known as the Yamato Bank[1] (see Fig. 1), which, besides including the islands of Oki,[2] extends northwards from the northern coast of southwest Japan. Its depth is 500–700 m. and is in the Japan Sea deep. According to Mr. H. Niino, dredging operations (Kamiya method) carried out by the Imperial Fisheries Experimental Station of Tokyo, on the continental shelf bordering Japan, have revealed the presence of considerable gravels and sands in that part of the Japan Sea where the granite pebble was discovered, and also on the sea-floor off the tip of the Noto Peninsula.[3] These facts show the distribution of pebbles on the bottom of the Japan Sea to be more than local.

The purpose of this paper is to call attention to the present discovery rather than offer a definite explanation of the presence of pebbles on the Japan Sea floor. The find is of interest because at no depth so great as 500 m. had the deposition of such pebbles been expected. A possible explanation is submergence of that part of the Japan Sea, where the pebbles were discovered.

Microscopic studies and petrographic comparisons of these pebbles with allied rocks from neighbouring shores may furnish a clue to the sources whence they have been derived, as well as to their geological age, and consequently to the age of the submergence, if submergence there has been.

This paper deals mainly with the granite pebble. Preliminary exami-

1) 大和堆. 2) 隠岐. 3) 能登半島.

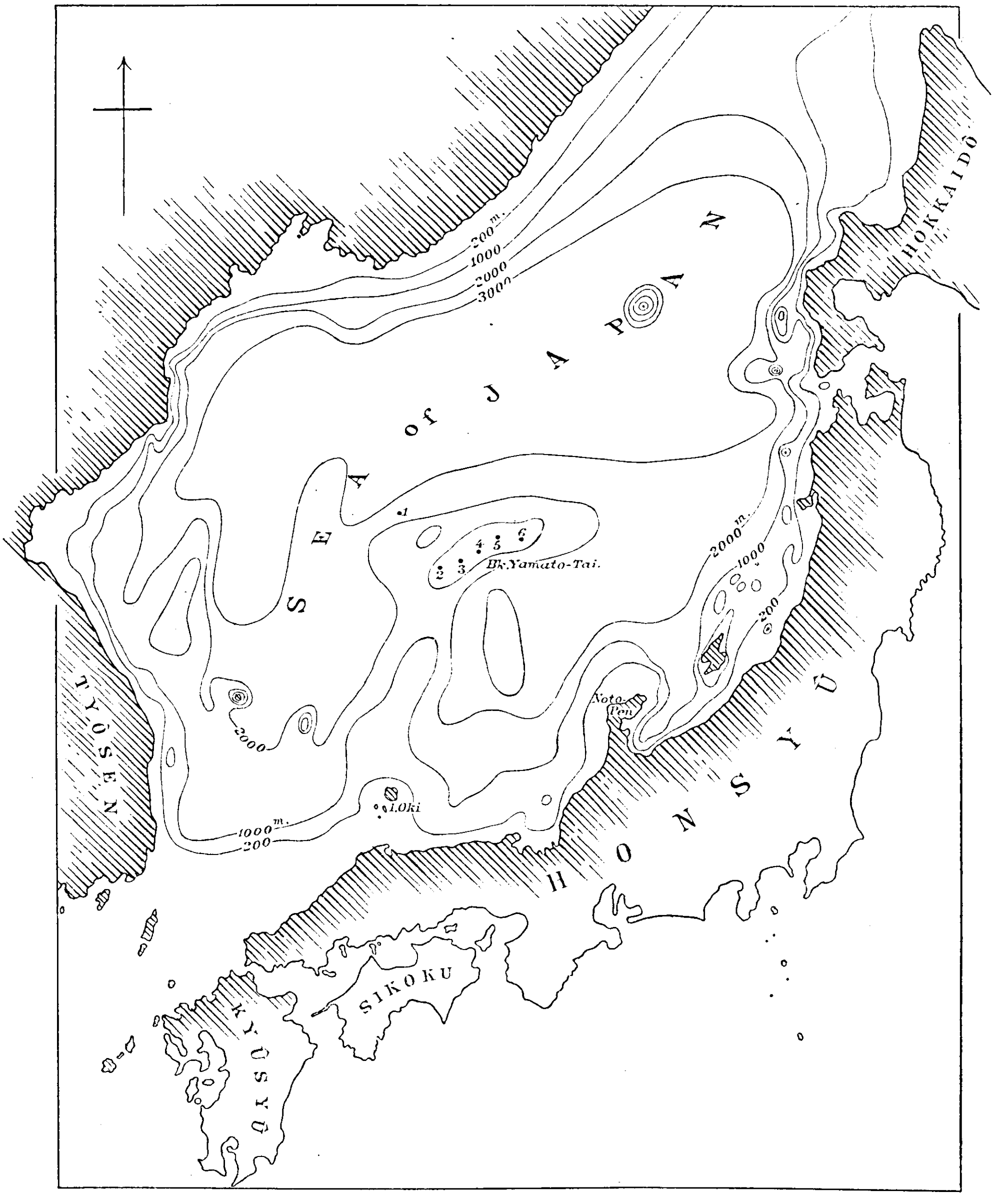

Fig. 1. Index map showing location of the pebbles.
Granite pebble from loc. No. 1; the other pebbles from locs. No. 2 and 5.

nations of some of the pebbles in the collection of the Imp. Fish. Exp. St., Tokyo, are also included, but their detailed studies are not yet completed.

Petrography of the Granite Pebble.

Megascopic Characters. The granite pebble is about 6 cm. in diameter, round, with polished surface. Its surface is greenish, but the inside is whitish, medium-grained, and consists of quartz, feldspar, and biotite.

Microscopic Characters. Under the microscope, the rock exhibits an allotriomorphic structure, seriate intersertal fabric. Quartz, orthoclase, plagioclase, biotite, with accessory apatite and zircon make up the constituent minerals (Pl. XCII, Fig. 1).

The quartz is anhedral, 0·1–3·0 mm. in diameter, and excepting a few extremely minute dust particles, is almost free from inclusions.

The orthoclase, which is anhedral, 0·5–1·0 mm. in diameter, is quite subordinate in amount to plagioclase. The plagioclase is anhedral, 0·1–3·0 mm. in diameter, and twinned according to the albite law, exhibiting very close polysynthetic lamellae. It is not zonally built, and is free from inclusions. The extinction angle in section normal to Z is : $X \wedge (001) = 2{\cdot}5°$. The refractive index as measured with a cleavage piece is : $n_{1D} = 1{\cdot}5438$ on (010). Accordingly, the mineral is identified as an oligoclase-andesine $Ab_{70}An_{30}$. Its interior is often turbid, owing to alteration to sericite.

The biotite is generally more or less idiomorphic, and forms distorted flakes, 0·05–1·0 mm. in length. It is intensely pleochroic, straw-yellow (X) to olivaceous black (Z). The refractive indices are : $\alpha_D = 1{\cdot}6029$, $\beta_D \fallingdotseq \gamma_D = 1{\cdot}6511$. Occasionally, it alters to a yellowish mineral (epidote) with high refractive indices.

Apatite occurs as small prisms, 0·05–0·1 mm. in length, or as equant crystals with the usual characters, being scattered through the rock but abundant particularly in and around the biotite crystals. Zircon, which forms little prisms, is rarely found.

Chemical Characters. The chemical analysis (by Mr. S. Tanaka) of the rock gave the results as shown in Table I.

According to the C. I. P. W. quantitative system, the rock belongs to *yellowstonose* (1. 4.″ 3. 4(5)). It may thus be classified with granodiorite or the quartz-diorite family rather than be called a typical granite. The normative plagioclase has the composition of oligoclase-andesine $Ab_{70}An_{30}$, being identical with the modal one.

Table I.

Bulk Composition	Wt. %	Norm Composition		Ratios
SiO_2	69·20	Q	27·45	
Al_2O_3	16·61	Or	9·68	$\frac{Sal}{Fem}=15·32$
Fe_2O_3	0·67	Ab	40·37	
FeO	1·70	An	17·25	
MgO	0·85	C	1·22	$\frac{Q}{F}=0·43$
CaO	3·67	Hy	4·22	
Na_2O	4·76	Mt	0·93	
K_2O	1·11	Il	0·61	$\frac{K_2O'+Na_2O'}{CaO'}=1·44$
H_2O+	0·73	Ap	0·31	
−	0·16			
TiO_2	0·29			$\frac{K_2O'}{Na_2O'}=0·16$
P_2O_5	0·11			
MnO	0·03			
Total	99·89			

According to Mr. H. Niino, the pebbles in the collection of the Imp. Fish. Exp. St., Tokyo, range in size from sand-grade to gravel with diameters exceeding 50 cm., and comprise many kinds of rock, the most common being quartzite, chert, graywacke sandstone, andesite, and plagioliparite. They are round or subangular, with polished surfaces

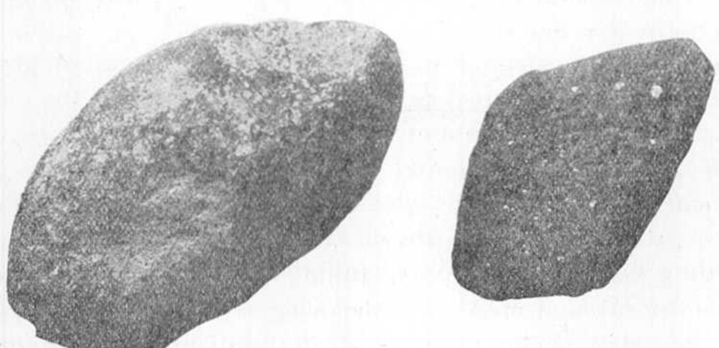

Fig. 2. Pebbles of augite-hypersthene-andesite (left) and olivine-basalt (right). Natural size.

(see Fig. 2). The writer obtained through the kindness of Mr. H. Niino some of these pebbles, of which the following will be briefly described.

1. Micropegmatite.
2. Hornblende-dacite.
3. Augite-hypersthene-andesite.
4. Olivine-augite-basalt.
5. Olivine-basalt.

1. *Micropegmatite.* (Pl. XCII, Fig. 2) Megascopically, this rock is gray, and almost aphanitic, but contains some megascopic feldspar. Microscopically, it is holocrystalline, and consists of phenocrystic plagioclase scattered through an equigranular mass that exhibits both micropegmatitic and microspherulitic—granophyric—texture. The phenocrystic plagioclase is euhedral to subhedral, 0·5–2·0 mm. in diameter, and is twinned according to Carlsbad, albite, and pericline laws. Zonal structure due to chemical difference is entirely absent. The maximum symmetrical extinction angle, which is about 15°, indicates an oligoclase-andesine, $Ab_{70}An_{30}$. The equigranular mass consists of quartz, orthoclase, and plagioclase, often exhibiting micrographic intergrowths of feldspar and quartz, and regular spherulitic aggregates of feldspar fibres. Besides the minerals above mentioned, we see pale greenish anhedral flakes of chlorite, 0·1–0·3 mm. in diameter.

2. *Hornblende-dacite.* (Pl. XCII, Fig. 3) Megascopically, this rock is gray, compact, aud sempatic with phenocrysts of plagioclase, quartz, and hornblende. Microscopically, it consists of phenocrysts of plagioclase, quartz, and hornblende, with accessory apatite and magnetite, scattered through a devitrified groundmass. The plagioclase phenocryst, which is euhedral to subhedral, 0·5–1·0 mm. in diameter, is twinned according to the albite and Carlsbad laws. Zonal structure due to chemical difference is moderately exhibited. Optic character: positive. Extinction angles in section normal to X are: $Y \wedge (010)=28°$, 17°, and 6°, in the central, middle, and marginal parts respectively of a zonally built crystal. The refractive indices measured with a cleavage flake are: $n_{1D}=1{\cdot}5432$, $n_{2D}=1{\cdot}5470$. Accordingly, the mineral is identified as andesine with an intermediate composition $Ab_{69}An_{31}$; while the zonally built crystals have a more calcic core $Ab_{49}An_{50}$ and a more sodic shell $Ab_{75}An_{25}$. The hornblende, which is euhedral to subhedral, occurs usually in prismatic habit with a length of less than 1 mm., but the mineral is entirely altered to chlorite and epidote, with an aggregate of minute grains of iron-ore. Quartz is subhedral, 0·3–1·5 mm. in diameter but is sometimes much indented with inlets of the groundmass. The cryptocrystalline groundmass is traversed by secondary quartz veinlets.

3. *Augite-hypersthene-andesite.* (Pl. XCII, Fig. 4) The majority of the pebble specimens in the writer's hands consists of this rock. Megascopically, it is dark gray to black, with greenish tints, compact, and porphyritic with phenocrysts of plagioclase and pyroxene. Microscopically, it is docrystalline in crystallinity, and dopatic. The chief constituent minerals are plagioclase, hypersthene, and augite, with accessory magnetite and interstitial glass. Plagioclase occurs as phenocrysts and as a constituent of the groundmass. The phenocrystic one is euhedral to subhedral, less than 1·5 mm. in diameter, and is developed in prismatic and of nearly equant habits, showing simple and polysynthetic twin-lamellae according to the albite, Carlsbad, and pericline laws. Zonal structure due to chemical difference is often very faintly exhibited. Extinction angles in section normal to Z are: $X \wedge (010) = -31°$ in the core and $-20°$ in the shell. Optic character: positive. The refractive indices measured with a cleavage piece are: $n_{1D} = 1{\cdot}5640$ and $n_{1D} = 1{\cdot}5683$ on (010). Accordingly, the mineral is identified as labradorite $Ab_{32}An_{68}$ with a more sodic shell. The plagioclase in the groundmass is dominantly lath-shaped, 0·1 mm. in length, and commonly twinned in two or three lamellae. In symmetrically cut sections the extinction angles do not exceed 24°, indicating an andesine with composition nearly equal to the shell part of the phenocrystic plagioclase.

Hypersthene occurs as euhedral phenocrysts of stout prismatic form, measuring 0·2–0·5 mm. along the longest direction, and is traversed by cracks perpendicular to the c-axis and sometimes by notable prismatic cleavage lines. The optical plane is parallel to the c-axis. Pleochroism is moderately exhibited with the following axial colors: X—brown, Y—yellowish brown, and Z—pale green. Monoclinic pyroxene is found as phenocrysts and as a constituent of the groundmass. The phenocrystic augite is subhedral, equant in habit, 0·2–0·5 mm. in diameter, and pale green to light yellow brown. It exhibits very faint zonal structure due to chemical difference. Parallel growth with rhombic pyroxene is rarely observed. The refractive index as measured with a cleavage flake is: $n_{1D} = 1{\cdot}6922$. The monoclinic pyroxene in the groundmass occurs in slender prismatic habit, 0·05-0·1 mm. in length, and is often twinned in two or three lamellae. Magnetite is scattered through the rock as equant grains, less than 0·1 mm. in diameter. The glass base, which is uniformly brown, is preserved with remarkable freshness. The rock, in bulk composition, contains 58·00 wt. per cent SiO_2.

4. *Olivine-augite-andesite.* (Pl. XCII, Fig. 5) This is a dense, dull

black rock with a few visible crystals of pyroxene. Microscopically, it is docrystalline in crystallinity, and is dopatic, with microphenocrysts of olivine and augite. Phenocrystic plagioclase is absent. The olivine is euhedral to subhedral, 0·05–0·2 mm. in diameter, and is much altered to a pale greenish substance with low double refraction and in parts to a reddish brown substance with higher double refraction. These alteration products of olivine are commonly surrounded by minute grains of iron-ore, preserving the outer form of the original mineral. There are numerous phenocrysts of augite with stout prismatic habit, 0·2–0·5 mm. in length, with a few up to 1·0 mm. The mineral, which is pale brown, often twinned after (100), shows remarkable undulatory extinction. The larger phenocrysts of the mineral exhibit faint zoning due to chemical difference. The refractive index as measured with a cleavage piece is: $n_{1D}=1{\cdot}6932$. Plagioclase, monoclinic pyroxene, and magnetite, with interstitial glass, make up the groundmass. The plagioclase occurs as simple or once-twinned prismoids, 0·03–0·15 mm. in length, and is in part disposed in fluxional arrangement. The mineral is too fine for accurate determination, but in symmetrically cut sections the extinction angles do not exceed 30°, indicating an acid labradorite ($Ab_{45}An_{55}$). The monoclinic pyroxene in the groundmass is pale brown, occurring as minute grains, less than 0·01 mm. in diameter, and also as prismoids, 0·03–0·1 mm. in length. Minute grains of magnetite are disseminated through the groundmass. The interstitial glass base is colorless. In bulk composition the rock contains 54·80 wt. per cent SiO_2.

5. *Olivine-basalt.* (Pl. XCII, Fig. 6) Megascopically, this rock is dark gray to black, compact, and aphanitic without a trace of phenocrysts. Microscopically, it is non-porphyritic, docrystalline in crystallinity with hyalopilitic texture, and consists of plagioclase, monoclinic pyroxene, and magnetite, with interstitial glass, except a few altered microphenocrysts of olivine. The altered olivine phenocrysts are anhedral, 0·4–0·7 mm. in diameter, and although generally pale green with low double refraction (antigorite?) are in parts yellow to reddish brown, and strongly pleochroic with higher double refraction (iddingsite). They are sometimes surrounded with grains of monoclinic pyroxene. The plagioclase occurs as simple or multiple-twinned prismoids of less than 0·15 mm. in length, but anhedral crystals up to 0·2 mm. in diameter are also present. The larger plagioclase crystals often exhibit zonal growth due to chemical difference. The mineral is too fine for accurate determination, but its extinction angle in an oriented section indicates a labradorite. The

monoclinic pyroxene, which is pale greenish brown, occurs as grains of less than 0·1 mm. in diameter and also as rods of 0·1 mm. length. Undulatory extinction of the mineral is strongly exhibited. Magnetite occurs as grains with diameters less than 0·05 mm. The colorless glass base encloses a fine dusty substance. In bulk composition the rock contains 53·00 wt. per cent SiO_2.

Comparison with Rocks of Neighbouring Shores.

The Japan Sea region comprising the Japan Sea coast-belts of Tyûgoku,[4] Oki Islands, Uturyôtô Island,[5] Saisyûtô Island,[6] Gotô Islands,[7] Tyosen (Korea), etc., forms a petrographic province characterised by the occurrence of various volcanic alkali-rocks effused during late-Tertiary and post-Tertiary. The pebbles as described above, however, do not contain any material characteristic of alkali-rocks, though they were collected from the sea-floor adjacent to or possibly included in the area of the province. All are of calc-alkali type, similar to what is extensively distributed in the Japanese Islands, such as Tyûgoku and elsewhere.

Compared with a specimen of the biotite-granite exposed extensively in the Tyûgoku district, the granite pebble shows finer grains of components, more calcic composition of the plagioclase, and lower refractive indices of the biotite. It is however not neccessary, nor is it to be expected that they shall be characteristic of the original granite, the parent mass of the pebble, for the granite mass might have had various petrographic characters according to the petrogenic process that went on during the cooling of the body; and further, as is seen from the examples in Table II, the components of one part of a granite mass might not have the optic properties that are found in another.

Under these circumstances, our petrographic study has not determined whether the granite pebble is derived from a certain mass now exposed in the Japanese Islands or not. The only thing of which we are positive is that the granite pebble has, as is clear from the foregoing description and from Table II, the general petrographic characters common to many Japanese granites, and which differ in many respects from the granites exposed on the continental side of the Japan Sea. The chemical composition of the pebble indicates that the rock belongs in the granodiorite or the quartz-diorite family rather than typical granite, containing as it does much normative plagioclase similar in

4) 中國. 5) 欝陵島. 6) 濟州島. 7) 五島列島.

Table II.

	Ab% in Plagioclase	Biotite, $\beta_D \doteqdot \gamma_D$
1	70	1·6511
2	83	1·6720
3	66	1·648
4	77	1·651
5	80	1·652–1·653
6	82	1·653–1·654
7	63–75	1·648
8	67–78	1·652
9	60–76	1·655

1. Japan Sea, 39°50′ N., 133° 50′ E. (Biotite-granite pebble from the sea-floor)
2. Morimoto, Prov. Tango.[8] (Biotite-granite)

3–6. Kasagiyama, Prov. Yamato.[9] (Biotite-granite)

7–9. Tukubasan, Prov. Hitati.[10] (Biotite-granite)

composition to the modal one ($Ab_{70}An_{30}$). The last character may be seen also in many Japanese granites.

The micropegmatite pebble is similar in petrographic characters to some of the dike-rocks intimately associated with many Japanese granite masses.

Of the pebbles of volcanic rocks, the augite-hypersthene-andesite bears a striking resemblance to the palaeotypal pyroxene-andesite (or palaeo-andesite) which occurs extensively in Tyûgoku and elsewhere as lava-flows, covered unconformably by lower Neogene (?) Tertiary formations. The pebble does not however show the alterations to which the palaeotypal andesite has occasionally been subjected.

As to the pebbles of dacite and basalt, we may also expect a close comparison with rocks of respective rock-type among the Japanese volcanics; and while petrographic evidences may point to an essentially Neogene Tertiary or Quaternary age, it is still premature to assign any exact dates to these pebbles.

Igneous-rock pebbles being the subject of this paper, accounts of

8) 丹後國森本.

9) 大和國笠置山, *cf.* M. Hotta, *MS.*, 1927.

10) 常陸國筑波山, *cf.* K. Sugi, *Jour. Geol. Soc.*, Tokyo, 34 (1927), 358.

other pebbles should be left for another occasion, but it may here be remarked that some of the pebbles are probably derived from sedimentary rocks similar to some of the upper palaeozoic formations distributed in Tyûgoku and elsewhere.

Summary and Conclusions.

Many pebbles of igneous rocks, both plutonic and effusive, and of sedimentary rocks were collected from a submarine ridge known as the Yamato Bank in the Japan Sea. They are round or subangular with well polished surface, and vary in size from sand-grade to gravel over 50 cm. in diameter. If these pebbles had been found only in a limitted area lying on the track of steamships, their presence might be attributed to ballast thrown overboard from passing vessels. But the distribution of the pebbles is evidence of its improbability. Neither is it likely that ocean currents transport pebbles of this size so far from the present shores. On the other hand, there can be no wearing down of the surface of hard rocks on the sea-floor with a depth of 500–600 m. The only alternative is that the sea-floor that yielded these pebbles was at one time either a land-surface or a shallow sea near the shore, when they were formed by erosive action of the water flowing over their respective parent rock-masses, the shores submerging later to their present depths.

All the pebbles described in this paper have the general petrographic characters common to their respective rock-types now exposed in the Japanese Islands. Hence it is inferred that the pebbles are derived from land which is now below the sea and which is geologically connected with the Japanese Islands, or that it was transported from some part of the present Japanese Islands before its submergence to where they lie on the sea-floor at present.

The granite pebbles does not show characteristics that could be correlated with any Japanese granite whose geological age has been established; while the andesite and basalt pebbles have characteristics common to the late-Tertiary and Quaternary volcanics in the Japanese Islands. It is therefore highly probable that the sea-floor where these pebbles exist was a land-surface or a very shallow sea near the shore during the post-Neogene. If the latest land-submergence had occurred in a very remote geological past, the pebbles could not have remained for long, geologically speaking, in the condition in which they are found at present without the aid of some auxiliary agent such as earthquake disturbances at the sea-bottom, since a sea-floor with a depth of 500–

600 m. acts as a settling basin for fine sediments and may be covered with deposits of mud and marine organisms soon after submergence. The wide distribution of the pebbles cannot be explained as due to such an auxiliary agent. Thus, the only explanation for the presence of the pebbles is *land-submergence in very recent geological time.*

The writer may here remark that recent land-submergence, to which he has ascribed the existence of pebbles at the bottom of the Japan Sea, was already deduced by Dr. H. Yabe from other evidence. According to him,[11] "the sea-floor now encircling the Japanese Islands to the depth of some 720 m., in the average, was once a land surface, and the land submerged below the sea level in a time geologically not very remote from the present. Prior to this great submergence of land, the Japanese Islands were elevated some 720 m. more than they are at present, and directly connected with the Asiatic continent." (See Fig. 3) He further believes that "the land connection of the Japanese Islands to the Asiatic continent was in full swing during the PN stage and continued to the end of the T stage."[12]

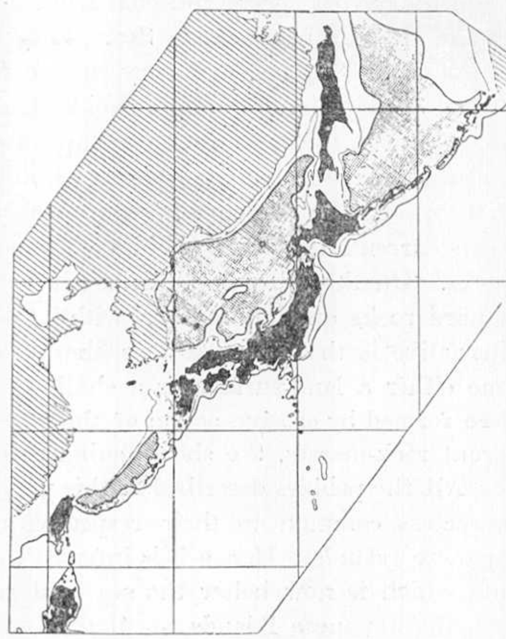

Fig. 3. Map showing distribution of land and sea before the submergence of some 720 m. of the sea-floor encircling the Japanese Islands (After Yabe).

Dr. Yabe's view cited above is essentially based upon the facts that along the coast of the Japanese Islands there are two submarine shelves of different depths, and that each of the submarine shelves carry traces of drowned valleys on its surface.[13] According to him, of the two submarine shelves the higher continental shelf is 150 m. deep on an

11) H. YABE, *Proc. Imp. Acad.*, 5 (1929), 167.
12) H. YABE, *Ibid.*, 430.
13) H. YABE and R. TAYAMA, *Record Oceanogr. Works*, Japan, 2 (1929–30), 1.

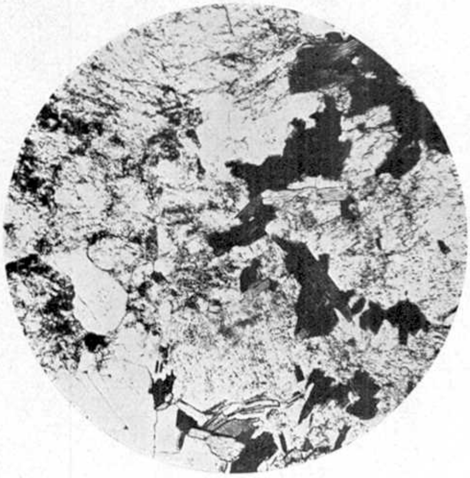

Fig. 1. Biotite-granite. × 41.
See p. 3.

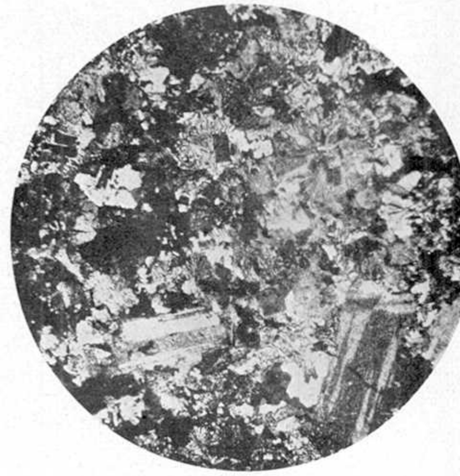

Fig. 2. Micropegmatite. × 41.
See p. 6.

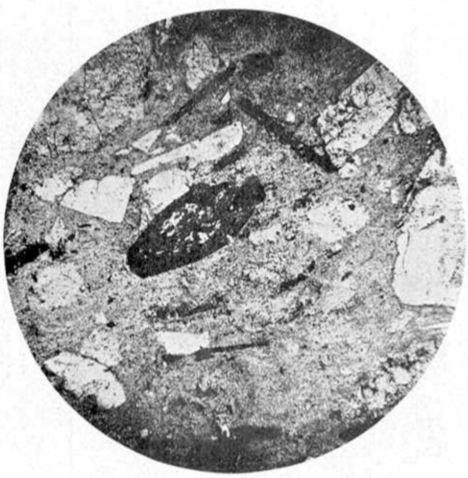

Fig. 3. Hornblende-dacite. × 30.
See p. 6.

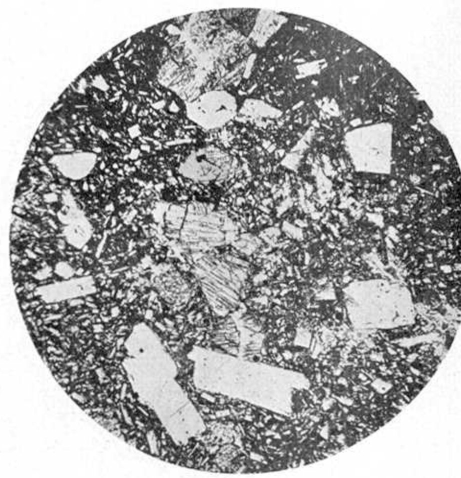

Fig. 4. Augite-hypersthene-andesite. × 41.
See p. 7.

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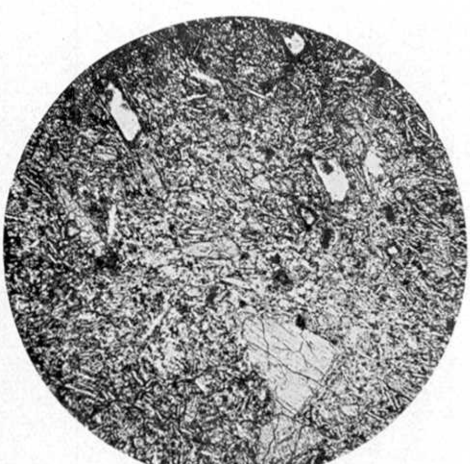

Fig. 5. Olivine-augite-andesite. × 41.
See p. 9.

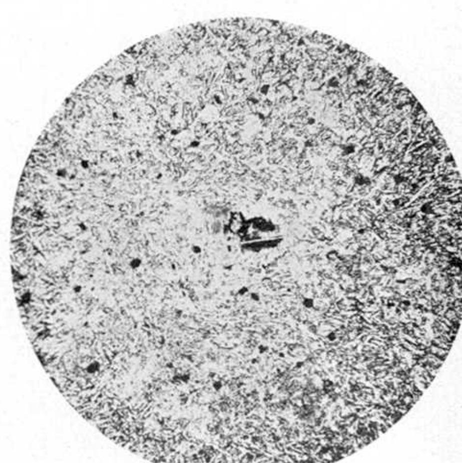

Fig. 6. Olivine-basalt. × 41.
See p. 9.

Microphotographs of the Pebbles collected from the Japan Sea Floor.

average along its outer margin, and the lower one, which is far less incomplete in form than the other, extends down to 720 m. These two are regarded by him as the prolongations respectively of the T and PN terraces[14] on the present land-surface of the Japanese Islands.

Thus, the present discovery of the pebbles and the inferences drawn from a petrographic study made of them may be strong evidences in support of Dr. Yabe's views concerning the epeirogenetic or eustatic movement of the Japanese Islands in recent geologic times, regardless of the cause, the magnitude, or the mechanism of the movement. Further studies of these pebbles may supply data that will afford more weighty evidence in favor of some particular age-span for the latest land-stage of the seas now bordering the present Japanese Islands.

In conclusion the writer desires to express his sincere thanks to Lieutenant-Commander Asahina, who supplied him with a piece of the granite pebble, and also to Mr Niino, through whose kindness the writer obtained many pebbles from the collection of the Imperial Fisheries Experimental Station of Tokyo.

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55. 日本海海底より採集せられたる礫に就いて

地震研究所　津　屋　弘　逵

昭和 6 年 8 月海軍水路部の一測量艦が日本海の測量に從事中、北緯 39°50′、東經 133°50′ 附近の深さ 453 m. の海底（所謂大和堆の北方）より一花崗岩礫を採集した。該礫は直徑約 5 cm. で圓味を帶び、中粒顯晶質で、石英、正長石、斜長石及び黑雲母を主成分として有する。日本內地の花崗岩に類似し、斜長石（オリゴクレース）の多いこと及び化學成分より見ると花崗岩といふよりむしろ花崗閃綠岩といふ方が適當かも知れない。

東京水産試驗場では以前より日本沿海海底の物質を採集してゐて、その採集品の中に多くの砂礫がある。之等は新野弘理學士によつて整理されてゐるが、同學士より得た數種の標本中には砂岩、硅岩等の水成岩の他にマイクロペグマタイト、角閃石•石英安山岩、複輝石•安山岩、橄欖石•輝石安山岩、橄欖石•玄武岩等の礫がある。之等は上述の花崗岩礫の發見せられた所より少し東南方の 500 m. 內外の深さの海底に於て採集せられたもののみであるが、新野學士によれば隱岐島の北方、能登半島の北方、佐渡の北西方等の何れも 500 m. 內外の深さの海底より多量の砂礫が採集せられてゐる。

かゝる礫が 500 m. 內外の海底に容易に採集し得る狀態にて存在することは非常に重大な意味を有することで、恐らく最近の陸地沈降を示すものであらう。礫の種類より見ればこの沈降は新第三紀又はそれ以後といふことが推定される。更に多くの礫を岩石學的に調べて日本內地の岩石と比較すると或はもつと限定された陸地沈降時代を知ることが出來るかも知れない。

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14) PN and T are abbreviated notations designating respectively Pre-Narita terrace and Tama terrace.