PSEUDOTECTITES FROM COLOMBIA AND PERU

by

R. MARTIN and C. DE SITTER-KOOMANS

(N.V. De Bataafsche Petroleum Mij., 's-Gravenhage, Petrologische Afdeling, Rijksuniversiteit te Leiden)

Introduction, summary and conclusions

In a previous note on "Americanites" (MARTIN, 1934) from Colombia and Perú, the writer came to the conclusion, on the basis solely of published data, that it was very likely that these so-called tectites are in reality obsidian of terrestrial origin. He stated, however, that "before it is possible to separate the americanites definitely from the tectites, a detailed field examination is required and also a minute determination of the chemical composition of the americanites and of the indubitable volcanic rocks from the neighbourhood."

A generous contribution from the Molengraaff-Fonds enabled the writer in the summer of 1934 to make a special study of tectites, in the course of which he visited the Mineralogical Institute at Jena, Germany, where he had occasion to study the Paucartambo (Perú) "tectite" and a few of the "tectites" from Colombia. This short investigation showed already that the flat-bottommed surface observed on the "tectite" from Paucartambo and on some obsidian spheres from Cali (Colombia) is not a part of the original surface of the "tectite" body but a subsequently developed fracture surface of slightly conchoidal shape, and should consequently not be explained as a flattening of the "tectite" due to falling from the heavens in a semi-plastic condition. The long paragraph dedicated to the explanation of this phenomenon in the former publication (p. 129) can therefore be stricken from the evidence presented in connection with the problem of the origin of these bodies.

While employed in Venezuela by the Caribbean Petroleum Company, the writer had occasion during three successive vacations to visit a number of the localities from which "americanites" had been reported and to make additional inquiries which might throw some further light on the question. From 26th to 29th May, 1942, he visited the surroundings of Popayán, Santander de Quilichao and Cali in the departments of Cauca and Valle del Cauca, Colombia, and succeeded in collecting a fair number of obsidian chips in the first named area. From 6th to 8th June, 1943, he visited San Agustín, department of Huila, Colombia, and obtained some obsidian chips encountered in the course of archaeological investigations in the neighbourhood of this village. On 20th October, 1944, he made a trip to Paucartambo in Southern

Perú, but failed to find any evidence of "tectites". Between 25th and 31st October of the same year, discussions with Dr Carlos V. NICHOLSON of the University of Arequipa and Dr Jorge A. BROGGI of the Geological Department of the Ministerio de Fomento at Lima, both in Perú, as well as various other persons connected with these institutions, led to the discovery of a large collection of "tectites" from Macusani, 157 km southeast of Paucartambo, which had not hitherto attracted the attention of their owners. It was later found than F. HEIDE had described these glasses in a publication dated 1936, to which the writer did not have acces until his return from South America after the war.

Mrs. C. DE SITTER-KOOMANS was so kind as to analyse the specimens collected by the writer in Colombia and Perú and has contributed to this paper the chapters on "Chemical composition" and "General considerations and comparison with tectites from other localities". Her conclusion that the "americanites" from Colombia are normal obsidians is in line with the field evidence presented by the writer, and they can therefore now definitely be classified as pseudotectites. Most striking is the close chemical relationship between the "americanites" from the Popayán area and the vitreous bomb found enclosed in a volcanic agglomerate on the slopes of the volcano Puracé. Supposedly, these obsidian chips and spheres are the product of a subrecent phase of the same volcanic activity which previously produced the obsidian bombs enclosed in the Popayán Formation.

As to the "macusanite", as the rocks from Macusani and Paucartambo will henceforth be designated (see below), their chemical composition indicates an intermediary position between sedimentary and igneous rocks. Since the field evidence is in favor of their interpretation as pebbles derived from an obsidian flow, it is submitted that the magma which produced this flow absorbed considerable quantities of sedimentary, presumably shaly material prior to eruption. The solution of the problem of the origin of the "macusanite" should be sought in the field, a remote part of the Peruvian Andes of which very little is known geologically and which the writer unfortunately did not have occasion to visit. However, its connection with terrestrial obsidian appears to be established by the evidence at hand and there are no indications favouring its classification as tectites.

Name

Since the discovery of true tectites in the state of Texas, United States of America (BARNES, 1939), the name "americanites" may lead to confusion, in particular since the available evidence appears to indicate that the "americanites" of Colombia and Perú are not tectites at all. The writer would therefore suggest that this name be dropped; it has never been generally used, anyway.

For the Colombian specimens, LA PAZ (1938) used the name Colombite, although STUTZER (1926) had previously pointed out that the name "Kolumbit" was already in use for another mineral. It is suggested that the name be not used again for the Colombian pseudo-tectites.

The obsidian from Macusani and Paucartambo with 16—20 % Al_2O_3 and containing crystals of andalusite and sillimanite is too different from any known type of obsidian to be classified as such and hence the new name "Macusanite" is proposed for it in this paper.

Occurrence [1].

HUBACH (1933) lists the following occurrences of "tectites" and obsidian in Colombia:

(1) Ascent of the road from Popayán te Coconuco, east of the crossing of the Rio Molino, in a volcanic agglomerate (Popayán Formation);
(2) Dispersed over the volcanic region of southern Colombia; scarce in the Popayán Formation, frequent in subrecent to recent deposits. Large pieces (fist size and larger) only near the volcano Puracé near Popayán. Small pieces of 2—4 cm diameter near Morales, Buenos Aires and Tuluá (compare localities 5 and 10, MARTIN, 1934, p. 124—125).

In the collection of the Geological Service at Bogotá, the writer saw obsidian chips collected by HUBACH in beds of the Popayán Formation up to recent age at the following localities:

(3) North and South of Buenos Aires;
(4) Morales, on top of a "Mesa" of Popayán Formation;
(5) Loma de la Tribuna, east of Timbío;
(6) Loma Guachinto, east of the railway station at Cali;
(7) Cuesta Mandibá.

The Popayán Formation consists essentially of volcanic deposits and is presumably of Pleistocene age.

In 1942 the writer visited the Popayán area briefly and collected quite a number of obsidian chips. The first object of his visit was the Tetilla, a steeply north dipping dyke or plug of diabase, which forms a prominent topographical elevation which appears pierced through the surrounding landscape of rolling hills formed by the horizontal beds of the Popayán Formation.

This hill (locality No. 3, MARTIN 1934, p. 124) lies approximately 14 kilometres to the west of the town of Popayán. Some 500 metres to the east of it is another dyke of andesite, which is connected with the Tetilla by a low ridge. No obsidian was found on the Tetilla itself, but in its immediate surroundings the writer collected:

9 pieces on the ridge between the Tetilla and the andesitic hill,
55 pieces on the andesitic hill east of the Tetilla,
1 piece on the trail from the Tetilla to the north, at the foot of the Tetilla,
1 piece between the Tetilla and Julumito on the trail from the Tetilla to the road Popayán — Tambo.
1 piece in the Quebrada Saté near the bridge on the same trail.

[1] Some corrections need to be made in the list of localities submitted by the writer in 1934, which was copied from other publicaions. On p. 124, locality No. 1, and on the following pages, Los Serillos should be spelled Los Cerrillos. On p. 125, third paragraph, and following pages, Loma de Cristalles shoud read Loma de os Cristales. On p. 130, tenth line, read Tuluá instead of Taluá.

In 1928, DE BOER included Nicaragua as a locality where tectites had been found, and LA PAZ (1938) considers the "tectites" from this locality to belong to the same group as those from Colombia and Perú. The writer is not familiar with this find and ignores the source of DE BOER's information.

All these were collected at the surface, mostly in black topsoil. It could be stated that none of them showed the bottle-green colour alleged by KÜCH (see MARTIN, 1934) and consequently, the corresponding remark on p. 127 (fifth paragraph) of the writer's former publication does no longer carry any weight.

Dr José María OBANDO R. of the Universidad del Cauca at Popayán showed the writer a fist-sized obsidian pebble rolled and worn by the Río Cauca, from which it had been collected in the neighbourhood of Popayán. He also produced a "tectite" which was claimed to have been observed to fall in the patio of a house in Popayán. He stated that obsidian chips were encountered in the Popayán area wherever the soil was being ploughed.

As the writer submitted in his former paper (1934) that the "tectites" found in the area of Popayán might be obsidian ejected by a volcano of the Andes, possibly the Sotará, he decided to carry out an investigation in that direction by making a trip along the road from Popayán to Tolima which crosses the Central Cordillera (the volcanic range of the Andes) north of the volcano Puracé; no road being available in the direction of the Sotará and time being too short for a trip on horseback. The road follows first the valley of the Río Molino, mentioned also by HUBACH, and at Kilometer 14 an outcrop of volcanic agglomerate was studied which correspond closely to HUBACH's description of the Popayán Formation along the road to Coconuco (which branches off at the river crossing a little further on). Effectively, the agglomerate yielded fist-sized, rounded bombs (diameter 5—6 cm) of transparent colourless glass which, however, had disintegrated into countless fragments, possibly upon cooling immediately after their deposition. This glass, which obviously corresponds to that designated as "tectite" by HUBACH from his locality (1) (see above), is very different from those found on the Tetilla, all of which are grey to dark grey in colour (although some may be so light as to be transparent in thin chips) and are found at the surface or in topsoil mostly as small fragments, rarely as entire bombs. The cause of this fragmentation, however, may have been the same that caused the glass bomb from the Popayán Formation to break up.

The colourless glass bombs recall the description of similar obsidians from Los Cerrillos, Uvales and Palacé around the volcano Sotará by VON HUMBOLDT (locality no. 1, MARTIN, 1934, p. 124). Their occurrence in a volcanic deposit resembles that of the small spheres of obsidian enclosed in a vitreous tuff along the Rio Quitcacé described by KÜCH (locality no. 4, l.c.), which might belong to the same formation.

Going further up the same road from Popayán to Tolima, the writer collected several dark obsidian chips of the Tetilla type in black topsoil at Kilometer 42, 4 km above the village of Puracé.

A trip on horseback in the neighbourhood of Santander de Quilichao (between Popayán and Cali) yielded no tectites, but the writer later received several obsidian chips, collected in this area by HUBACH, from Dr Benjamin ALVARADO B. of the Geological Service at Bogotá. The formation in this area consists of andesite breccias and tuffs of the lower part of the Popayán Formation, and the obsidians have been found at the surface on top of these beds.

Another trip by the writer to the Loma (Cerro) de los Cristales, west of the town of Cali, was also unsuccessful. The hill consists of diabase with geodes, the walls of which are covered by small quartz crystals (hence the

name of the hill), but no obsidian was found either on the hill or in an outcrop of conglomerate at its base.

Considering that, if the obsidian was derived from a volcano of the Central Cordillera of the Andes such as the Puracé, it should also be found on the east side of this mountain range, the writer in the following year visited the archaeological site of San Agustín near the headwaters of the Río Magdalena, which runs parallel and to the east of the Cauca Valley, in which Popayán and Cali are situated. Although he did not find any obsidian himself, he was later presented with several good specimens of the Tetilla-type by Dr Gregorio HERNANDEZ DE ALBA of the Archaeological Service at Bogotá.

In the year following this trip, the writer had occasion to visit Cuzco, the old Inca capital of Perú, and on this occasion made an excursion by car to Paucartambo, the site from which LINCK had described a "tectite" with crystals of andalusite and sillimanite. The high mountain ranges on either side of this village consist of Silurian shales. No "tectites" were found either along the road or in the river bed along the village, and an investigation in Paucartambo itself, which included a thorough inventory of the school collection, yielded no results whatsoever. There was also nobody at the University of Cuzco who was familiar with these objects. A visit to the University of Arequipa, however, paid off on a large scale. The drawers of the geological collection of this university yielded no less than 107 specimens closely fitting the description of LINCK's. They had been donated by Dr. Gustavo Corso MASÍAS, who, in turn, had obtained them from J. Wenceslao MÁLAGA at Macusani, 157 km southeast of Paucartambo. A further search in Arequipa led to the discovery of one more specimen in the possession of Dr. Corso MASÍAS, four belonging to Filiberto MÁLAGA y M., a brother of Wenceslao, one in the collection of William F. JENKS, geologist of the Cerro de Pasco Copper Corporation, donated by the university, and one owned by G. Rivera PLAZA of the geological department of the Ministerio de Fomento at Lima, given to him by Dr Otto WELTER; a total therefore of 114 specimens.

The most striking discovery was that 20 of these were clearly stratified, which is a typical property of obsidian flows and very different from the turbulent flow structure of real tectites. Another property which appeared to range these glasses with obsidian rather than with tectites was that several of them were of a red colour completely unusual in tectites, even though the majority had a light green colour comparable to that of some tectites. The crystals of andalusite, sillimanite and other minerals described by LINCK were clearly visible with the naked eye in a number of specimens. According to texture and colour, the 114 specimens can be sub-divided as follows (see Table page 156).

According to Filiberto MÁLAGA, these glasses occur in the region north of Macusani, west of the Río Sangaban and east of the Cordillera de Caravaya, over an area of 60 by 60 kilometres or more, in creeks which run through horizontally bedded volcanic strata of light grey colour with large black crystals (andesite?). Smaller, smooth and brilliant specimens (obsidian chips?) are said to occur on the pampa above Macusani. Dr Corso MASÍAS claims that they occur on either side of the Cordillera de Caravaya and to the southeast as far as Sandia. The relationship with a volcanic formation appears therefore to be as well established as in the case of the Colombian

Colour		*Unstratified*	*Stratified*	*Total*
Light green		66 (one with vertical texture) Weight 8.4—561.5 gr. (entire pieces) Sp. Gr. 2.360	13 (stratification of gas bubbles)	79
Light green with dark green spots	lighter green	15	4 Weight 17.2—681.7 gr. Sp. Gr. 2.360 (fragments)	19
	darker green	2		2
Green with red spots		8 Sp. Gr. 2.356 Weight 51.5—328	2 (one stratified green with thin upper stratum of red) 5 gr. (fragments)	10
Red		3 (one with vertical texture) Weight 24.6—332.0 gr. (fragments) Sp. Gr. 2.361	1 (black bands)	4
Total		94	20	114

"tectites". Subsequently, the writer saw in the collection of the geological department of the Ministerio de Fomento at Lima obsidian chips found between Chalhuanca and Puquío in South Perú, also on top of volcanic deposits of recent age.

If we add to these 114 specimens the 5 from the neighbourhood of Macusani described by HEIDE and the one from Paucartambo described by LINCK, we have in all 120 specimens of "macusanite" of the following characteristics:

	Number of specimens	Weight (grams)	specific gravity	Refractive index (Na)
Arequipa collection	114	8—682	2.360—2.361	N.D.
Jena coll. (Macusani)	5	9—375	2.345—2.361	1.4862
Jena Coll. (Paucartambo)	1	520	2.3595	1.4855

HEIDE also noticed that most of the specimens were transparent and of a very light brownish green colour, like the Paucartambo specimen, but the largest one was for the greater part reddish brown and opaque. The lower than average specific gravity of some of HEIDE's specimens is most likely due to the few included gas bubbles. His observations on the enclosed crystals are in line with those of LINCK.

Collections

Of the Colombian obsidian chips collected or received from others by the writer, 12 from the Tetilla, 2 from Santander de Quilichao and 1 from San Agustín were sent to Mr. Virgil E. BARNES of the Bureau of Economic Geology, University of Texas, Austin, Texas, U. S. A.; the remainder are in the Rijksmuseum van Geologie en Mineralogie, Leiden, Holland. In Arequipa, the writer received 11 of the specimens held by the University of Arequipa, one from Dr Corso MASÍAS and two from Filiberto MÁLAGA, a total of 14, of which 5 were sent to Mr. BARNES and 9 remain in Leiden.

Chemical composition

At the request of Dr. MARTIN I made some analyses of the pseudo-tectites from Colombia and Peru.

The pseudo-tectites from Colombia

Thin sections were made from the obsidian chips from different localities. All slides had the same character, to wit glass without the slighest trace of crystallisation.

We thought that two analyses ought to suffice for this macroscopically and microscopically uniform rock type (table I).

TABLE I

	1	2	3	4
SiO_2	75.75	75.31	76.64	76.37
TiO_2	—	—	—	0.11
P_2O_5	—	—	—	0.02
Al_2O_3	10.24	11.66	12.23	12.59
Fe_2O_3	2.03	2.41	1.63	0.26
FeO	0.31	0.25	0.27	0.48
MnO	0.05	0.04	0.05	0.14
MgO	0.26	0.28	0.24	0.17
CaO	0.98	1.10	1.15	0.79
Na_2O	3.21	2.72	3.86	3.36
K_2O	5.43	5.72	3.17	4.67
H_2O+	0.39	0.38	0.34	0.97
H_2O-	0.31	0.22	0.23	—
	99.96	100.09	99.81	99.93
si	457	446	476	493
al	40	40	45	47.5
fm	14	15	11	6.5
c	6	7	8	5.5
alk	40	38	36	40.5
Q	57.7	58.1	60.8	60.1
L	37.6	37.5	36.3	38.0
M	4.7	4.5	2.9	1.9

1. Obsidian chip from the andesitic hill E of the Tetilla, near Popayán.
2. Obsidian chip from the neighbourhood of Santander de Quilichao.
3. Glass bomb from volcanic agglomerate, Km 14 of the road Popayán-Coconnco.
4. Tetilla near Popayán, STUTZER and DÖRING, 1928.

The analyses 1 and 2 are very much alike, the differences are so small that we cannot expect that further analyses would reveal other particularities. The analysis no. 3 has the same character, although there is a slight difference in the alkalines, Na_2O is higher than in the case of nos. 1 and 2. But otherwise the similarity is so clear, that the conclusion that no. 3 comes from the same volcanic eruption is highly probable. The analysis no. 4 by STUTZER & DÖRING originates from probably the same material. The difference of this analysis with the first two is pronounced: principally a somewhat higher SiO_2, much lower Fe_2O_3 and a somewhat lower K_2O content.

In the Niggli-values the difference comes out mainly by the higher Al-value. Although the sum of the K_2O and Na_2O percentages is lower, the alk-value is also higher, due to the lower c- and fm-values.

Obviously he lack of crystallised matter precludes an understanding of the above mentioned differences. On the other hand the disparities do not implie totally different rock types, as will be shown later on.

Pseudo-tectites from Macusani, Peru (plate)

Two analyses were made, no. 5 of the red-brown type, no. 6 of the green-gray type (table II).

TABLE II

	5	6	7
SiO_2	70.82	70.67	70.56
TiO_2	0.00	0.00	—
P_2O_5	Trace	0.27	—
Al_2O_3	16.93	16.12	20.54
Fe_2O_3	0.95	1.33	—
FeO	0.39	0.41	0.96
MnO	0.08	0.06	—
MgO	0.19	0.18	0.11
CaO	1.02	2.07	0.78
Na_2O	4.34	3.30	3.42
K_2O	4.58	5.53	3.41
H_2O+	0.31	0.19	0.83
H_2O-	0.23	0.18	—
	99.84	100.31	100.61
si	362	352	364
al	51	47.5	62.5
fm	7	8	5
c	5.5	11	4.5
alk	36.5	33.5	28
Q	52.3	53	55.5
L	42.8	43.9	32.8
M	4.9	3.1	11.7

The thin slides of these specimens show in no. 5: crystals of sillimanite, zircon, andalusite, staurolite, and mica in a glass matrix, and in no. 6: crystals of andalusite, zircon, sillimanite, mica and cordierite in a glass matrix.

Neither the chemical nor the mineralogical composition show any prominent differences between the two types.

The only disparity is that the K_2O- and the Na_2O-percentages are about equal in no. 5, but in no. 6 the K_2O-content is 2 % higher than the Na_2O. The sum of the alkalies is equal in both 5 and 6.

When we compare the "tectite" of Paucartambo, described by LINCK, with our specimens we find that qualitatively the mineralogical content is identical.

However, the chemical composition (no. 7, table II) shows pronounced differences, as LINCK found a much higher Al_2O_3-content and a lower K_2O-content.

From the description by HEIDE, published in 1936 in a short note on 5 specimens from Macusani, the identicity of these with the one from Paucartambo was confirmed, although no chemical analyses were available.

General considerations and comparison with tectites from other localities

We calculated the Niggli-values of our pseudo-tectites in order to compare them with the chemical analyses of tectites and magmatic rocks.

In the diagram fig. 1 we plotted our pseudo-tectite values between

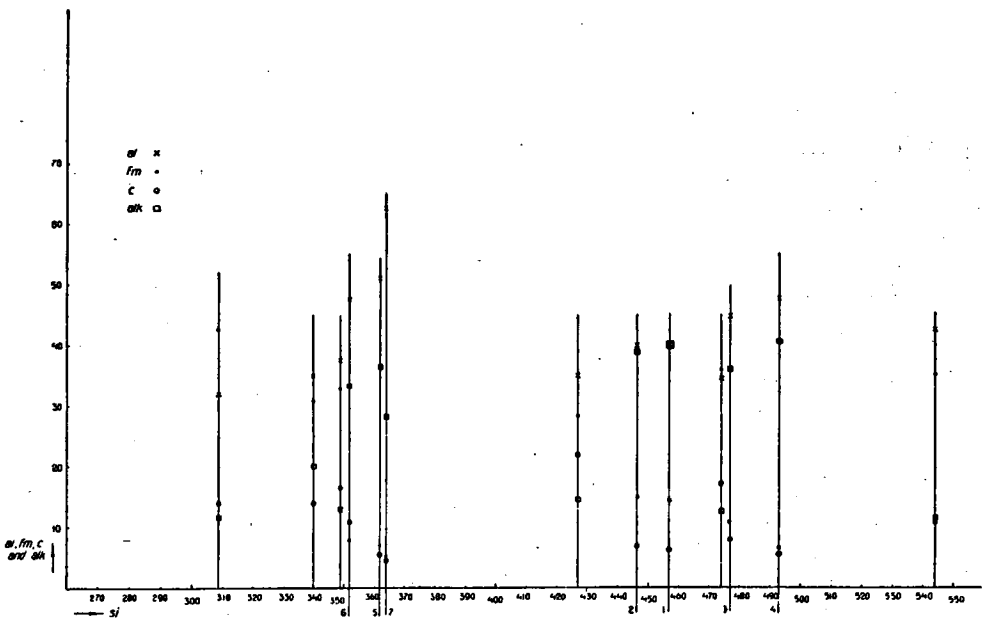


Fig. 1.

those of other tectites (compare MARTIN, 1934). We are struck immediately by the great difference of the pseudo-tectites and the tectites.

The tectites show alk-values far below the al- and fm-values, whereas the alk-values of the pseudo-tectites are much higher than the fm-values, although lower than the al-values.

When we compare the pseudo-tectites from Colombia with the diagram of the normal atlantic magmatic rocks (fig. 2), we see that our analyses 1, 2, 3 and 4 have the same character. The alk-values are lower than the al-, but far higher than the fm-values at the same si.

The analyses of the pseudo-tectites from Peru (nos. 5, 6 and 7) deviate somewhat from the atlantic diagram; at the same si the al-values are higher, the alk-value is equal or somewhat lower, and the fm- and c-values are lower. As could be expected, no. 7 deviates most.

This comparison of the chemical analyses shows very clearly that the

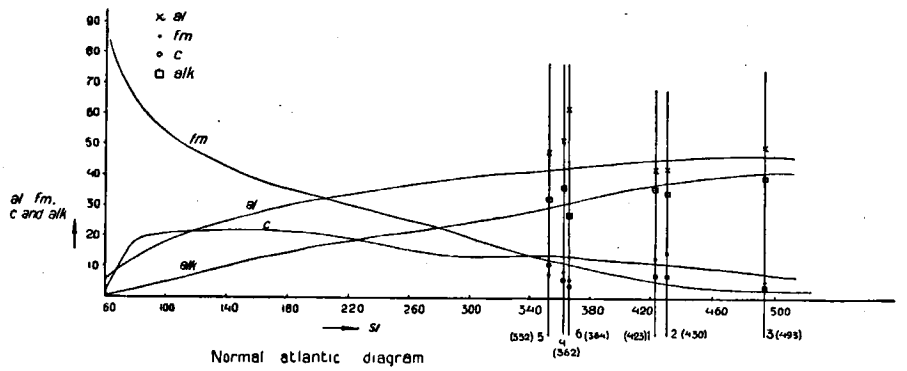


Fig. 2.

pseudo-tectites from Colombia and Peru do not agree with the tectites. The Colombian rocks are certainly normal obsidians. The Peruvian rocks indicate either molten sediment solidified as glass, or an obsidian containing some molten sedimentary material, for which MARTIN proposes the name "Macusanite" (see above).

Because the origin and source of the tectites is still an unsolved problem, we have tried to eludicate the relation between pseudotectites and tectites, sedimentary and magmatic rocks by putting them in Q-L-M-diagrams (compare P. NIGGLI).

In table III we give the calculated Q-L-M-values of different tectites and fig. 3 gives the positions of the tectites and pseudotectites in the triangular diagram. Their positions are arranged in a zone parallel and near to the Q-X-side of the triangle.

When we compare this diagram with that of the magmatic rocks, we see that only the pseudo-tectite points lie within the magmatic field, and in particular that part of the field, which represents the granitic rocks (fig. 4d), above the line P—F. Below this line of SiO_2 saturation are siuated the basic magmatic rocks (fig. 4e).

Point E is the quartz-felspar eutecticum on the Q—L-line which moves down along ED, parallel to Q—M with increasing femic content of the rocks.

The field QEDP is base of magmatic rocks except along the line ED.

Quite another picture gives the diagram of sedimentary and metamorphic rocks as published by HASLER, who gave the diagrams of the paragneisses and amphibolites (fig. 4b) and Bündnerschiefer (fig. 4c) from the Tessin and of sedimentary rocks of a marly- and limy-type, phyllites and argillaceous

TABLE III

	Q	L	M
Columbia (1)	56.4	39.1	4.5
„ (2)	57.4	38.3	4.3
„ (3)	60.8	36.3	2.9
„ (4)	60.1	38.0	1.9
Peru (5)	52.3	42.8	4.9
„ (6)	53	43.9	3.1
„ (7)	55.5	32.8	11.7
Tektite Java	59	25	16
„ Siam	60	29.4	10.6
Australite	62.5	25.3	12.2
„	68.5	21.5	10
„	73.6	14.4	12
Moldavite	66	26	8
„	70	20	10
„	75	18	7
Queenstownite	84.5	4	11.5
„	87	6.5	6.5

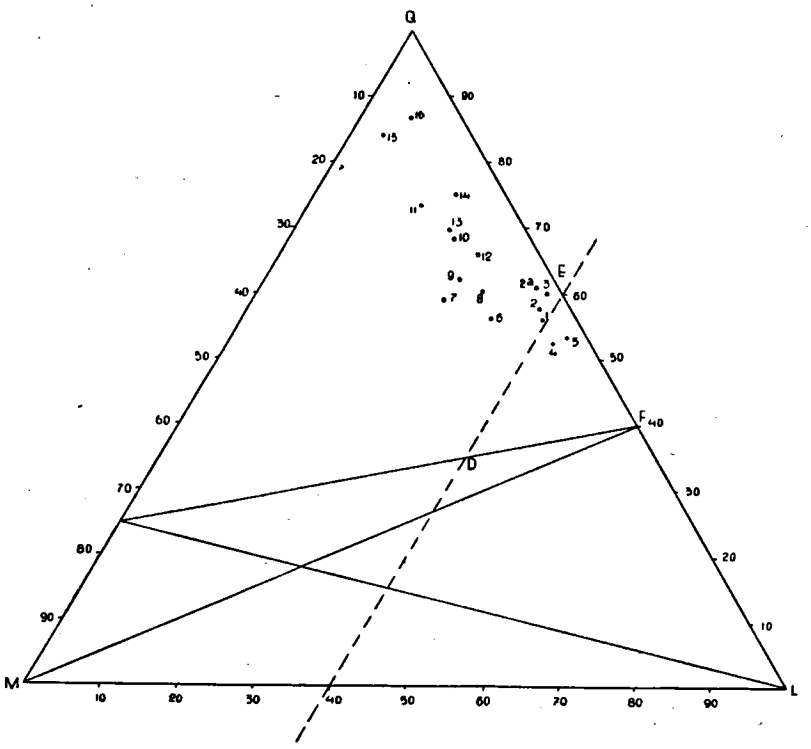


Fig. 3.

schists (fig. 4a). He omitted analyses of sandy and arcosic sediments as there were too few analyses available. In particular the Bündnerchiefer and sedimentary rocks show a multitude of points in the QEDP-field. The tectites compare therefore very well with the sedimentary rocks.

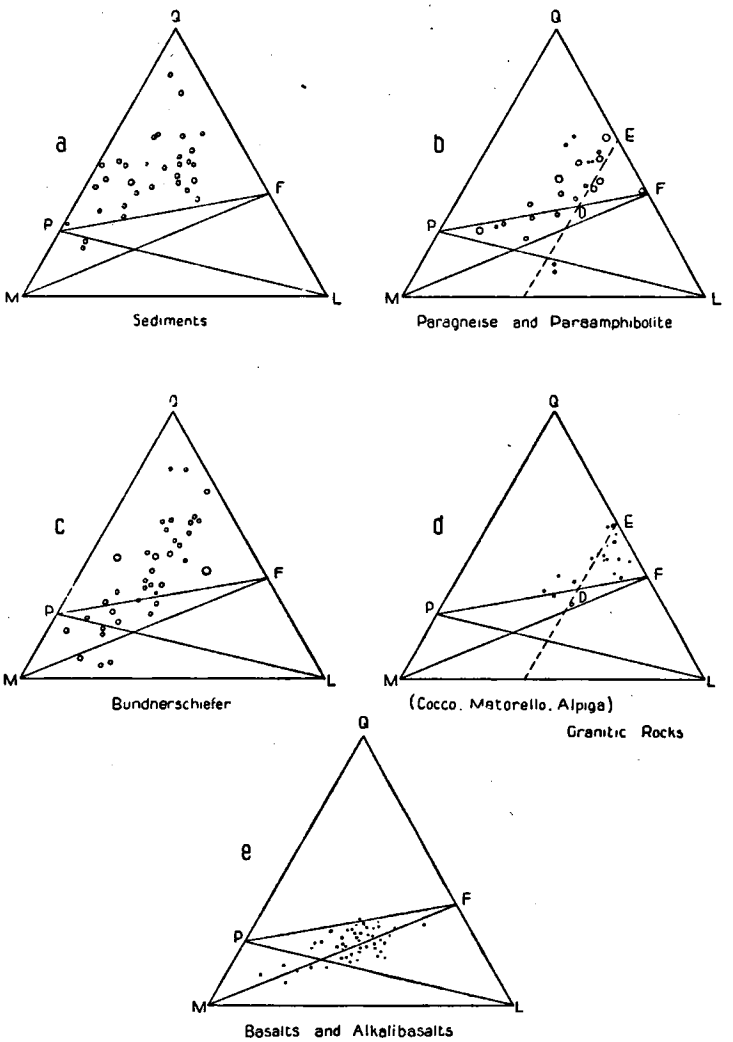
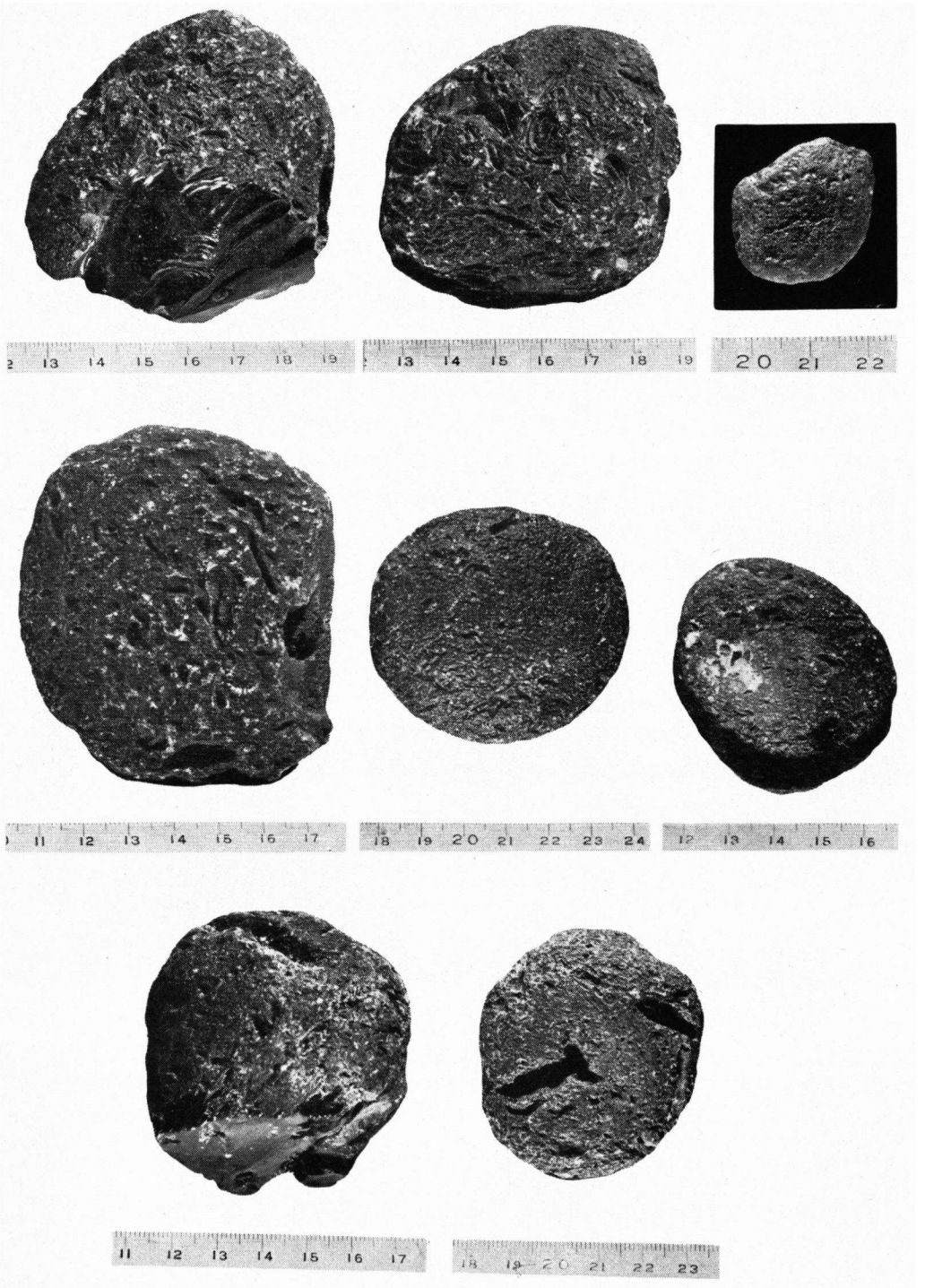


Fig. 4.

PLATE I

Pseudo-tectites from Macusani, Péru.
Upper and middle row: transparent, light brownish green specimens.
Lower row: reddish brown, opaque specimens.

Plate I



Whether we can conclude from this evidence that tectites are molten sediments is doubtful, however. The macusanites appear to occupy an intermediate position between the sedimentary and magmatic rocks.

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[2] Quoted by MARTIN (1934) as "1921 (title unknown)".