5. *The TITANIFEROUS BASALTS of the WESTERN MEDITERRANEAN :*
A PRELIMINARY NOTICE. By DR. HENRY S. WASHINGTON,
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I. INTRODUCTION.

IN the summer and autumn of 1905 the volcanic districts of Catalonia, Sardinia, Pantelleria, and Linosa were visited by me, and their rocks collected under the auspices of, and with the aid of a grant from, the Carnegie Institution of Washington. During the past year, the abundant and representative material thus brought together has been the object of microscopical and chemical study, which is still in progress. The final results of these investigations are to appear elsewhere, as separate papers dealing with the rocks of the several districts; but some observations and conclusions of a general character appear to be sufficiently well-established, and of enough interest, to justify their publication in advance of the more detailed descriptions.

It is the object of the present communication, which I have the honour of laying before the Society, to call the attention of petrologists to the existence, in the Western Mediterranean Basin, of a hitherto unrecognized petrographic province, or comagmatic region, to adopt a term used by me elsewhere, one of the most salient characters of which is the presence of *salfemanes* (basalts) that contain remarkably-high amounts of titanium. The data available at present are far from complete, as only a small proportion of the numerous rock-types have been analysed: the analyses so far made by me being mostly of basalts (*salfemanes*), with fewer of the more *salic* rocks. Furthermore, there are several gaps in the comagmatic zone, at localities which I was unable to visit, and the rocks of which are still imperfectly known.

So far as it goes, however, the evidence at hand indicates that the volcanic rocks of Catalonia (including the volcanoes near Olot and Gerona), the extensive basaltic sheets of Tertiary age and those of the two great volcanoes of Monte Ferru and Monte Arci, as well as the lavas of the small recent cones, in Western Sardinia, and the volcanoes of Pantelleria and Linosa (a small islet to the south-east of Pantelleria), possess certain chemical and mineralogical features in common, which point to some genetic relationship between them. In other words, the existence is indicated

of a comagmatic region (petrographic province) extending in a rather narrow zone from Linosa on the south-east, north-westward through Pantelleria and Sardinia, and possibly through the volcanoes of the southern French littoral to Catalonia. The possibility of the further extension of this zone in a southerly direction, along the eastern coast of Spain, will be discussed subsequently.

For the present, we must confine our attention to the most femic rocks of the region, the basalts in common parlance, for the study of which numerous specimens and thin microscopic sections, and some twenty chemical analyses, are available. Only brief petrographical descriptions need be given here, and elaborate discussion of the analyses is omitted. But attention may be specially called to the mineralogical similarity among the basalts, which obtains all along the line: labradorite, augite, and olivine being uniformly the predominant and essential minerals, with accessory but constant amounts of a titaniferous magnetite and apatite, and in some cases accompanied by subordinate amounts of nephelite. Hornblende and biotite are either entirely absent from the saffemanes of the region, or present in a few rare types. The concordance in chemical composition is most noticeable in the low alumina, the abundance of the iron-oxides (ferrous oxide being greatly in excess of ferric), the relatively rather high amount of soda, the uniformly-high figures for titanium-dioxide, and the almost constant presence of notable quantities of nickel.

Owing to the incompleteness of the earlier analyses of the rocks of these localities which have been examined chemically, such as those of Monte Ferru by Prof. Doelter and of Pantelleria by Dr. Fœrstner, and the total lack of analyses of the rocks of Catalonia, Linosa, and of most of the Sardinian occurrences, the petrological connection between these localities and the peculiar chemical features of their basalts have not been suspected until recently. The first, and so far the only, petrographer to note their highly-titaniferous character was Fœrstner,¹ who found 5.86 per cent. of titanium-dioxide in the basalt of the island of 1891 near Pantelleria, and who suggested that this constituent was probably present in similar amounts in the basalts of Pantelleria and Graham's Island (1831), as well as in those of Etna. More recently, the probability of some relationship between the lavas of Sardinia, Pantelleria, and (possibly) Linosa was pointed out by me,² although the possibility of any connexion with the Spanish rocks was not thought of.

II. PETROGRAPHICAL DESCRIPTIONS.

The saffemanes (basalts) are, with very rare exceptions, of common types, presenting no very peculiar or specially-noteworthy features, either in the hand-specimen or under the microscope. In

¹ Tscherm. Min. Petr. Mitth. vol. xii (1891) p. 520.

² Am. Journ. Sci. ser. 4, vol. viii (1899) p. 293.

colour (when fresh) they vary from a medium grey, as in some of the massive flows near Olot and some of the Tertiary sheets of Sardinia, to very dark grey or black, the darkest lavas being those of the most recent cones of Catalonia, Sardinia, Pantelleria, and Linosa. They vary from very compact forms to highly-vesicular ones, the smaller cones in all the districts being composed very largely of spongy scoriæ. As a rule, these lavas are not highly porphyritic, some being quite aphyric megascopically, although in most of the specimens small phenocrysts of augite and olivine are present, with small tabular phenocrysts of felspar in some cases. A peculiar characteristic of certain lavas of Catalonia, Sardinia, and Linosa, is the presence of rounded nodules of olivine of a light yellowish-green colour and coarsely-granular structure. These may attain very considerable dimensions, 4 or more inches in diameter; and near Scano, at Monte Ferru, they are accompanied by smaller, but more compact, nodules of a greenish-black augite. Large plates of a bronzy biotite are found in a leucitic basalt which occurs sparingly at Monte Ferru; but hornblende is never seen in the specimens collected, although it was found as loose crystal-fragments in tuffs on the island of Linosa.

In thin section, the mode of mineral composition is seen to be quite uniform, though varying within limits. A plagioclase-felspar, usually a labradorite, is abundant, commonly with tabular development and much twinned. With it is occasionally seen some orthoclase, but the amount of this is always very small and usually quite negligible. Next to the plagioclase, augite is the most abundant mineral. This is quite colourless in thin section, and occurs as stout, subhedral, prismatic phenocrysts, which are frequently fragmentary, as well as in the usual small prismatic groundmass-crystals. It seldom forms anhedral, interstitial areas between the felspar-tables, so that an ophitic texture is very rare. Olivine is rather abundant and quite constant, although in some of the types, especially those of Sardinia, it is absent or present in negligible amount; while in other rare cases it surpasses the augite. It presents the usual features, is colourless, varies from anhedral to subhedral, or even euhedral forms, with the common planes, and in the less fresh specimens shows the well-known yellowish-brown border.

These three minerals—labradorite, augite, and olivine—are the predominant and essential constituents of all the basalts; but with them constantly occur smaller amounts of magnetite and apatite, in the usual forms of small anhedral of the former and prisms of the latter. In some cases, especially at the Catalanian volcanoes, there is a colourless base which the analysis shows must possess the general composition of nephelite, since there is insufficient silica for the formation of felspars. But nephelite, in euhedral and distinctly-recognizable crystals, is rare in the *salfemanes*, though it occurs in some of the Catalanian basalts, and in some of the more salic rocks in Sardinia and Pantelleria. A few of the basalts of Monte Ferru and elsewhere in Sardinia show some very small spheroidal anhedral

of what is apparently leucite, though the only analyses yet made of these types render the identity of this mineral somewhat uncertain. Hornblende is never seen in the thin sections of any of these rocks, but phenocrysts of biotite occur in one rare type at Monte Ferru, as mentioned above.

As might be expected from the chemical composition, ægirite is not present in these *salfemanes*, nor do the augites proper appear to carry much of the ægirite-molecule. It may be mentioned here that, in the more *salic* rocks, in which its presence might be looked for, ægirite is not a common mineral, although the occurrence of the soda-hornblende, *ænigmatite*, in some of the Pantellerian lavas is well known; but it appears to be far less abundant than is commonly supposed.

Concerning the textures little need be said. They are those usual in such *femic* eruptive rocks, but the generally very slight megaphyric development may be noted, as well as the almost complete absence of true ophitic textures. Many of the basalts, especially the more compact ones, are holocrystalline, while others are more or less vitreous, the vesicular forms consisting largely of glass, which is either dark in colour, or dusty and opaque with very numerous, minute, black microlites.

III. CHEMICAL COMPOSITION.

The chemical composition of these basalts is shown in the accompanying table (I, pp. 74-75), which includes only a portion of those analyses that have been made by me. Those here presented are regarded as representative of the majority of the *salfemanes* (basalts) of the several districts, and most of the other available examples much resemble them in their essential features.

The methods of analysis were those commonly employed in the United States.¹ The alkalis were determined by the Lawrence-Smith method, and titanium-dioxide by the colorimetric method of Weller. The latter, it may be remarked, is far more accurate, as well as more expeditious, than the gravimetric method so often employed; and, as the figures for titanium-dioxide are in all cases the means of three closely-agreeing determinations, they may be relied upon. Combined water ($H_2O +$) was determined directly by Penfield's method, since the loss on ignition gives rise to very misleading figures, owing to the oxidation of the large amounts of ferrous oxide present in these rocks. Some of the analyses here presented are not complete, although sufficiently so for the object immediately in view, and are to be amplified in the future by determinations of some minor constituents, such as zirconia, nickel-monoxide, manganous oxide, cuprous oxide, and baryta. In their present form, therefore, they are to be regarded as provisional, although the corrections involved by such determinations in the figures given here will be presumably of small magnitude. It may

¹ W. F. Hillebrand, 'Some Principles & Methods of Rock-Analysis' Bull. U.S. Geol. Surv. No. 176 (1900); and H. S. Washington, 'Manual of the Chemical Analysis of Rocks' New York & London, 1904.

be remarked, however, that the low summations of some of the analyses are undoubtedly due to these non-determinations, especially of nickel-monoxide and manganous oxide.

Of these analyses, the first four are representative of the Catalanian basalts, No. 1 of the volcanoes near Gerona, 2 of the more felspathic camptonose (felspar-basalt)-flows, 3 of the abundant limburgose (nephelite-basalt)-flows, which filled the valleys near Olot, and 4 of the scoriaceous lavas of the numerous small, recent cones. The next four include representative Sardinian basalts: No. 5 of some of the extensive Tertiary sheets, 6 & 7 of the basaltic mantles of Monte Ferru and Monte Arci respectively, and 8 of the small recent cones, the last manifestations of volcanic activity in the island. The next two are of typical basalts of Pantelleria, followed by analyses of the highly-scoriaceous lavas of the most recent submarine eruptions in the neighbourhood of Pantelleria.¹ The next two analyses (13 & 14) are of the, as yet undescribed, basalts of the island of Linosa: the former being a representative of the solid lava-blocks found in the earlier phase of tuff-volcanoes, and the latter of the more recent lava- and scoria-cones. Finally 15, 16, & 17 are the early analyses by Dr. H. Föerstner, which are tabulated for comparison with Nos. 9, 11, & 12.

As regards the main constituents, these rocks present the following characters. Silica varies considerably, the highest figures being found in the lavas of Sardinia, while in some of those of Catalonia and Pantelleria they are rather low. Alumina is rather low as a rule, and this constituent follows silica very closely, the two rising and falling together. The oxides of iron, taken together, are uniformly high, the totals varying from 10 to 13 per cent., except in the Sardinian rocks, where somewhat lower figures are met with. In every case ferrous oxide surpasses ferric oxide, the amount of the former being frequently very great as compared with that of the latter, as in Nos. 10, 12, & 14. Magnesia and lime are not very high for basalts, the former varying considerably, while the amounts of the latter are more constant, the lowest figures for both being found in the Sardinian rocks. The alkalis, while not very high, are sufficiently so in those rocks lowest in silica to give rise to normative, as well as modal, nephelite, while the soda is uniformly dominant over the potash.

Of the minor constituents, titanium-dioxide is the most notable. This constituent is present in every case in very large amounts: large, that is, for this substance, the average amount of which in igneous rocks is 1 per cent. or less. Indeed, the higher figures found in the table are unparalleled elsewhere, except in titaniferous ores, as was mentioned above. It is lowest in the Sardinian basalts, somewhat higher in those of Linosa, still higher in the Catalanian rocks, and reaches its maxima in those of Pantelleria

¹ The specimen represented by No. 11 was very kindly given to me by Prof. E. S. Dana, while that represented by No. 12 was bought some years ago of Mr. Butler, of Brompton Road, London, S.W.

TABLE I.—ANALYSES OF WESTERN

	1	2	3	4	5	6	7	8
SiO ₂	44.55	47.66	44.29	44.82	49.00	52.40	52.79	52.67
Al ₂ O ₃	12.48	14.36	12.62	14.06	15.63	15.26	16.45	15.35
Fe ₂ O ₃	2.81	2.83	3.61	4.56	4.03	0.74	2.74	3.82
FeO.....	8.54	8.44	8.84	7.27	5.00	8.33	6.44	5.42
MgO.....	10.85	8.19	10.06	8.60	7.86	7.45	5.56	4.40
CaO.....	7.99	9.36	9.23	9.56	8.16	7.33	6.51	5.91
Na ₂ O.....	4.04	3.51	3.25	3.69	3.93	3.54	3.64	4.50
K ₂ O.....	2.57	1.54	1.82	2.30	2.60	0.99	1.21	2.68
H ₂ O+ ...	0.56	0.17	0.21	0.30	0.13	0.29	1.02	0.37
H ₂ O- ...	0.18	0.20	0.09	0.05	0.18	0.06	0.21	0.14
TiO ₂	4.32	3.83	4.92	4.25	3.25	3.12	2.64	4.04
P ₂ O ₅	0.70	0.45	0.57	0.67	0.63	0.49	0.39	0.75
SO ₃	0.05	n.d.	0.05	n.d.	n.d.	n.d.	n.d.	n.d.
NiO.....	n.d.	n.d.	n.d.	n.d.	n.d.	0.06	0.18	n.d.
MnO.....	n.d.	n.d.	n.d.	n.d.	n.d.	0.08	0.06	n.d.
BaO.....	n.d.	n.d.	0.06	n.d.	n.d.	n.d.	n.d.	n.d.
Totals ...	<u>99.64</u>	<u>100.54</u>	<u>99.68</u>	<u>100.13</u>	<u>100.40</u>	<u>100.14</u>	<u>99.84</u>	<u>100.05</u>

1. Monchiquose; Llorá, near Gerona (Catalonia).
2. Camptonose; Castelfullit, near Olot (Catalonia).
3. Limburgose; Las Planas, near Olot (Catalonia).
Includes 0.02 ZrO₂ and 0.04 SrO.
4. Limburgose; Monte Sacopa, near Olot (Catalonia).
5. Andose-camptonose; Tres Nuraghes (Sardinia).
6. Camptonose; Cuglieri, Monte Ferru (Sardinia).
7. Andose; Uras, Monte Arci (Sardinia).
8. Akerose; Monte San Mateo, Ploaghe (Sardinia).
9. Camptonose; Monte Sant' Elmo (Pantelleria).
10. Camptonose; dyke in tuff, Costa Zaneti (Pantelleria).

TABLE II.—NORMS OF WESTERN

	1	2	3	4	5	6
Quartz .....	.....	.....	.....	.....	.....	0.54
Orthoclase.....	15.57	8.90	11.12	13.34	15.57	6.12
Albite	10.22	24.63	15.20	13.86	25.15	29.87
Anorthite	10.84	19.18	14.18	16.12	17.24	22.80
Nephelite	12.92	2.56	6.82	9.51	4.26	.....
Diopside	19.17	19.59	22.02	21.03	15.37	7.88
Hypersthene.....	.....	.....	.....	.....	.....	24.15
Olivine	17.19	12.88	14.10	9.98	9.09	.....
Magnetite	4.18	4.18	5.34	6.73	5.80	1.16
Ilmenite	8.21	7.30	9.42	8.06	6.23	5.93
Apatite	1.68	1.00	1.34	1.68	1.34	1.34
	III. 6.2.4	III. 5.3.4	III. 6.3.4	III. 6.3.4	II-III. 5.3.4	III. 5.3.4

MEDITERRANEAN BASALTS.

9	10	11	12	13	14	15	16	17
46·22	45·72	48·97	44·83	46·55	48·84	49·87	49·24	44·64
12·23	12·45	16·37	11·73	14·55	14·62	14·80	19·06	12·74
4·91	1·57	1·33	1·35	3·17	2·08	8·25	1·77	4·21
7·71	12·01	8·56	11·79	7·88	9·00	6·88	10·33	11·17
6·74	5·29	6·22	5·50	8·61	7·15	6·77	5·00	5·82
9·86	9·58	7·49	9·63	8·75	9·33	9·36	8·75	10·12
3·39	3·40	4·09	3·34	3·71	2·86	2·81	3·89	4·31
1·13	1·08	1·72	1·40	1·62	0·89	0·68	1·19	1·41
0·17	0·40	0·38	0·81	0·14	0·49	0·45	0·63	0·51
0·05	0·01	0·08	0·10	0·03	0·07			
5·68	6·43	3·95	6·88	3·84	3·57	n.d.	n.d.	5·86
1·46	1·54	1·04	2·14	0·55	0·36	n.d.	n.d.	n.d.
n.d.	n.d.	n.d.	n.d.	n.d.	0·05	n.d.	n.d.	n.d.
n.d.	0·15	0·08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
n.d.	0·16	0·06	n.d.	n.d.	n.d.	n.d.	n.d.	0·20
n.d.	n.d.	n.d.	n.d.	n.d.	none.	n.d.	n.d.	n.d.
<u>99·55</u>	<u>99·79</u>	<u>100·34</u>	<u>99·50</u>	<u>99·40</u>	<u>99·31</u>	<u>99·87</u>	<u>99·86</u>	<u>100·99</u>

11. Andose; Graham's Island (1831), near Pantelleria.
12. Camptonose; Island of 1891, near Pantelleria.
13. Camptonose; block in tuff, Il Fosso (Linosa).
14. Camptonose; Monte Pozzolanà (Linosa).
15. Basalt; San Marco (Pantelleria). Analysis by H. Fœrstner, *Tscherm. Min. Petr. Mitth. n. s. vol. v* (1883) p. 393.
16. Basalt; Graham's Island, near Pantelleria. Analysis by H. Fœrstner, *ibid.* p. 391.
17. Basalt; Island of 1891, near Pantelleria. Analysis by H. Fœrstner, *op. cit.* vol. xii (1891) p. 512.

MEDITERRANEAN BASALTS.

7	8	9	10	11	12	13	14
4·50	1·20	.....	.....	.....	.....	.....	.....
7·23	16·12	6·67	6·12	10·01	8·34	9·45	5·56
30·92	38·25	28·82	28·82	34·58	28·30	23·32	23·58
24·74	13·34	14·73	15·57	21·13	12·79	18·35	24·46
.....	.....	.....	.....	.....	.....	4·40	.....
3·80	8·64	19·54	18·67	7·91	17·22	17·05	15·46
17·22	7·00	8·06	5·91	.....	5·21	.....	17·88
.....	.....	0·28	6·08	14·44	6·78	13·53	0·93
3·92	5·57	7·19	2·32	1·86	2·09	4·64	3·02
5·02	7·75	10·79	12·16	7·45	13·07	7·30	6·84
1·00	1·68	3·36	3·36	2·35	5·04	1·34	1·00
II. 5.3.4	II. 5.2.4	III. 5.3.4	III. 5.3.4	II. 5.3.4	III. 5.3.4	III. 5.3.4	III. 5.3.4

and the neighbouring submarine eruptions. It may be mentioned, in this connexion, that two pantellerites of Pantelleria, with 69.79 and 66.07 per cent. of silica, yielded respectively 0.89 and 0.92 of titanium-dioxide, which are unusually-high figures for such quaric (acid) rocks. In a general way, titanium seems to follow the iron, and runs inversely with the silica.

Phosphoric pentoxide is distinctly abundant and, like titanium, seems to follow the iron-oxides, the highest figures being found in the rocks of Pantelleria and the neighbourhood. Chlorine (derived from sea-water) is present in some of the Linosa rocks, but has not yet been determined, whence is due in part the low summation of No. 14. Nickel seems to be almost constantly present, even in the Sardinian lavas, often in considerable amounts for this constituent; and its presence is to be regarded as one of the characteristic, though minor, chemical features of the region. Although only occasionally determined as yet, its presence was established, as in the Catalanian and Linosa basalts, by the faint greenish tinge of the filtrate from the ammonia-precipitate, the amounts being approximately those of the quantitatively-determined occurrences, judging from the depth of colour. The small amounts of manganese usually found do not call for remark. It is probable that copper, the presence of which was sometimes indicated, exists only as traces, although this is a point which is to be the object of future study. Zirconium, barium, strontium, and sulphur, when looked for, were found to be absent, or present in scarcely more than traces.

Coming back to the abundance of titanium, the question naturally arises as to what mineral or minerals carry it. It is clearly not present in the feldspars, and neither titanite nor ilmenite could be detected in any of the thin sections. While the matter is still under investigation, the available data indicate that a large proportion of it is present in titaniferous magnetite, with probably somewhat less in the augite, and little (if any) in the olivine. No separations have yet been made of the rock-minerals, but an analysis of a dark-green augite-nodule from a leucitic lava of Scano (Monte Ferru) gave 1.91 per cent. of titanium-dioxide, while an olivine from the same locality contained only 0.10 per cent.¹

As the augites of these rocks are almost, if not quite, colourless in thin section, their richness in titanium may be doubted, as it is commonly supposed that highly-titaniferous augites show a brownish-violet colour.² It has, however, been shown recently that the green augites of Central Montana,³ and the pale-green or colourless augites of Central Italy,⁴ are markedly titaniferous, one of the latter carrying 2.85 per cent. of titanium-dioxide.

¹ A black hornblende, found as loose crystals on Linosa, yielded as much as 8.47 per cent. of titanium-dioxide, the highest figure yet recorded for this mineral.

² F. Zirkel, 'Lehrbuch der Petrographie' vol. i (1893-94) p. 284; and H. Rosenbusch, 'Mikroskopische Physiographie der Massigen Gesteine' 4th ed. vol. i (1905) 2nd half, p. 208.

³ L. V. Pirsson, *Am. Journ. Sci.* ser. 4, vol. xx (1905) p. 39.

⁴ H. S. Washington, 'The Roman Comagmatic Region' *Carnegie Inst. Publ.* No. 58 (1906) p. 134.

IV. CLASSIFICATION OF THE ROCKS.

The classification of these lavas according to the prevailing systems has been sufficiently indicated in the foregoing pages. For the most part, they are felspar-basalts, with fewer nephelite-basalts, these last occurring especially in Catalonia and not having been, as yet, definitely determined from the other districts. These basalts are usually olivine-bearing, although in Sardinia olivine-free types are rather common.

The classification according to the quantitative system is based on the figures furnished by the analyses, and on the calculated norms, which latter are shown in the appended Table II (pp. 74-75). In this the norms are numbered as in Table I of Analyses, and the symbols representing the class, order, rang, and subrang are given in each case below.

The great majority of the basalts lie within the *salfemane* class, the exceptions being some of the Sardinian basalts and that of Graham's Island, which are in *dosalane*, these being distinctly higher in normative felspar, especially albite and anorthite, than the others. Outside of Catalonia, where normative (and modal) nephelite is so abundant as to cause some of the types to fall in the sixth order, with felspars dominant over nephelite, the order is uniformly the fifth; that is, the quantities of either quartz or nephelite are negligible as compared with the felspars. The rang is almost as uniformly the third, with alkalies and salic lime in about equal amounts, and in only two cases are the alkalies dominant over salic lime (Nos. 1 & 8). The relation of the alkalies is very constant, soda being dominant over potash in every case, so that the subrang is invariably the fourth.

Although, in the *salfemanes*, the femic¹ constituents form about one half of the rock, their relations, as expressed in the minor divisions of grads and subgrads, may be disregarded in the present brief discussion, as unnecessarily prolonging it, and introducing what may seem to be a superfluous refinement into the present introductory and little tried stage of the new classification.

As illustrative of the correlation of the two systems of classification, a few points may be dwelt on very briefly. While all those rocks, which are free from nephelite, would be called basalts in the prevailing systems, it will be observed that the distinctions between them are more numerous according to the quantitative system. The basalts of Pantelleria and of Linosa are uniformly in *camptonose* (in *salfemane*), as are also many of those of Catalonia. On the other hand, many of those of Sardinia fall in *andose* or *akerose* in

¹ It is to be remembered that the term 'femic' applies only to the standard, non-aluminous minerals, like ideal diopside, hypersthene, olivine, or magnetite. Such 'ferromagnesian' minerals as augite, hornblende, or biotite, which contain alumina, are termed 'alferric,' and their molecules are resolved into salic and femic components in the calculation of the norm. It may thus happen that a rock with augite very much more abundant than plagioclase (and hence at first glance apparently *dofemic*) is actually in the *salfemane* class.

the dosalane class, thus clearly indicating by their systematic names their great content in silica and alumina, and their lesser content in the femic constituents, such as iron-oxides, magnesia, and titanium-dioxide.¹ These Sardinian basalts, furthermore, are almost the only basalts that show in the norm high hypersthene (which enters into modal augite), and little or no olivine, and the comparative rarity of this last mineral among them has been noted above.

Again, the basalts of Catalonia, which are almost the only basalts with recognizable nephelite under the microscope, are similarly the only ones to fall in order 6, with notable amounts of this mineral in the norm. Finally, it was pointed out on a previous page that in this series lime is not very high, that is, for such basaltic rocks: and this feature is revealed in the magmatic position of these types in alkalicalcic rangs, or even in domalkalic ones: whereas, as has been pointed out elsewhere,² the majority of 'basalts' fall in docalcic rangs, such as hessase or auvergnase.

It should be borne in mind that the new names used here express only the magmatic (chemical) characters of the rocks. The mineral and textural features are to be expressed according to the proposed system by qualifying compound adjectives, or eventually by typl adjectives. But further discussion of these and cognate topics is uncalled for here.

V. EXTENT OF THE REGION.

The real extent of this zone or region of chemically and mineralogically similar rocks is as yet problematical, and its full discussion must be reserved for the future. The possible richness of the Etna basalts in titanium, and their connexion with those of Pantelleria, has been suggested by Dr. Fœrstner in an article cited above. But no complete and trustworthy analyses of these lavas are available, those of Sartorius von Waltershausen, Jewett, Silvestri, and Ricciardi being manifestly at fault as regards either accuracy or completeness, or both combined. In their figures for silica, the oxides of iron, lime, and the alkalies, the Etna lavas are much like the Pantellerian basalts; and the high figures for alumina commonly reported may be due, in part to admixture with magnesia (which is commonly low), and in part to the non-separation of titanium-dioxide, which would be precipitated and weighed with it.

Along the southern coast of France are several 'basaltic' volcanoes, as at Montpellier and Agde, and it is possible that these may eventually turn out to be connecting links between those of Sardinia and Catalonia, but their chemical characters are quite unknown to me. A volcanic zone, in which 'basalts' occur, extends south from Catalonia along the eastern coast of Spain, including the Columbretes

¹ Exceptions to this rule are apparently presented by Nos. 5 & 6, but No. 5 (with less silica than the others) is near the dosalic border of selfemane, while in No. 6 the higher magnesia and lime (as compared with those of Nos. 7 & 8) serve to throw the rock into the selfemane class (camptonose), despite its high silica.

² H. S. Washington, U.S. Geol. Surv. Prof. Paper No. 14 (1903) p. 75.

Islands, the neighbourhood of Cartagena, Cabo de Gata, and Alboran Island. But their rocks demand further chemical investigation, the earlier analyses either neglecting the titanium or giving rise to uneasiness on the score of accuracy. In a recent highly-interesting paper¹ Dr. A. Osann has described the rocks of two localities in Murcia, and his description is accompanied by careful and complete analyses by Dittrich. These do not show the high amounts of titanium which we might expect if the rocks belong to the same region as that dealt with here, although they are somewhat higher than the average in this constituent.

A possible extension southward from Linosa is indicated by the occurrence of a phonolite at Msid Gharian, near Tripoli, described by Prof. L. van Werveke.² The possible connexion of the rocks of Pantelleria with those of Abyssinia and the Great Rift Valley in East Africa, has already been suggested by Dr. G. T. Prior.³

DISCUSSION.

The PRESIDENT expressed the gratification with which the Society received this paper, as a recognition from the Author of his election as one of the Society's Corresponding Fellows. The paper was an extension of the work which, for some years past, the Author had been carrying on in the basin of the Mediterranean. It showed the same firm grasp of petrographical methods, the same reliance on minute and accurate chemical analysis, and the same successful co-ordination of facts in the natural history of rock-groups. The high percentage of titanium in the rocks now described was a point of considerable interest and importance, and seemed to justify the Author's separation of the region of the Western Mediterranean as a distinct petrographical province, so far at least as regards its later basaltic eruptions.

Dr. TEALL agreed with the President in his estimate of the value of the paper, which dealt with a very interesting and somewhat peculiar group of rocks. The Author had done much to give definiteness and precision to our chemical knowledge of igneous rocks, and he (the speaker) felt sure that all the Fellows would welcome this communication.

Dr. J. W. EVANS thought that the paper emphasized the importance of exact and complete analytical work, especially in connexion with the minor chemical constituents. He had had the opportunity of examining numerous concentrates of the heavy minerals of sands, and was struck by the prominent place taken by ilmenite and other titanium-bearing minerals. He also drew attention to the large percentage of titanium-oxide which is often present in bauxite, usually a product of the decomposition of igneous rocks; and expressed his belief that many other occurrences of rocks rich in titanium would be discovered.

¹ 'Ueber einige Alkaligesteine aus Spanien' Rosenbusch Festschrift, 1906, p. 263.

² L. van Werveke, Neues Jahrb. vol. ii (1880) p. 275.

³ Min. Mag. vol. xiii (1903) p. 228.