A note on the occurrence of potassium-rich trachytes in the Kaiserstuhl carbonatite complex, West Germany

By D. S. Sutherland, B.Sc., Ph.D., L.R.I.C., F.G.S.

Department of Geology, The University, Leicester

[Read 25 September 1967]

Summary. Specimens of trachyte obtained on a recent visit to the Kaiserstuhl are compared with similar potassium-rich rocks from carbonatite complexes in Africa. Two new chemical analyses are given, in which the values for alkalis (Na_2O 1·21, K_2O 12·63; Na_2O 0·92, K_2O 12·18 %) are of interest.

In April 1965, the author was privileged to visit West Germany on an interchange scheme sponsored by the British Council, and was able to examine some of the classic areas of alkaline igneous activity associated with the Rhine graben. The Kaiserstuhl represents a dissected volcano of Miocene age, situated in that part of the graben where Mesozoic and Tertiary sediments are down-faulted between the predominantly crystalline massifs of the Vosges and the Schwarzwald. The complex has been mapped and described in detail in recent years by Wimmenauer (1957, 1959*a*, 1959*b*, 1959*c*, 1962*a*, 1962*b*, 1963, 1966) and the results of further studies by a team of workers have been published by Euratom (van Wambeke, 1964).

Volcanic rocks, which are preserved on the flanks of the complex, comprise tephrites, tephritic agglomerates and phonolitic tuffs, limburgite, and subordinate nephelinite. In the central part of the complex, intermittent exposures in the thick blanket of loess reveal an intrusive complex consisting of a variety of essexites with phonolites, and an area of carbonatite that occupies approximately 1 Km^2. The intrusive silicate rocks of the centre in many places form dyke-complexes, but several bosses or plugs of phonolite penetrate the intrusive centre, the volcanic rocks of the flanks, and the surrounding sediments. The carbonatite occurs as a number of apparently contiguous diapiric bodies emplaced in the silicate rocks of the centre.

The rocks that form the subject of this short paper were collected from the eastern slopes of the Orberg ridge, which lies to the east of Schelingen (fig. 1). There are no actual exposures, but rock fragments

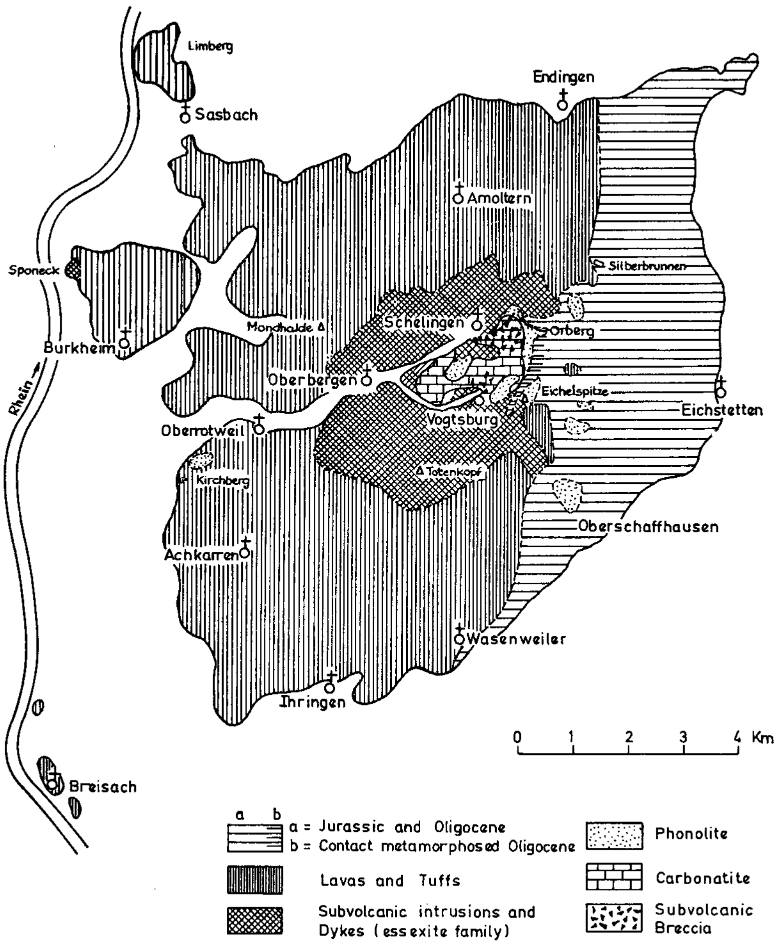

FIG. 1. Geological sketchmap of the Kaiserstuhl complex, omitting superficial loess. (Redrawn from Wimmenauer in van Wambeke, 1964, p. 18.)

on the surface appear to be representative. They consist of light buff-coloured rocks in which feldspar is the most obvious mineral, either in the form of a felt of fine laths or as phenocrysts up to 8 mm in length. Although mapped as phonolite, these rocks are lighter in colour and bear a strong resemblance to certain intrusive trachytes occurring in eastern Uganda (Sutherland, 1965).

Two specimens were collected, and have proved on subsequent examination and chemical analysis to have a trachytic composition. They are, furthermore, similar to the feldspathic rocks associated with carbonatites in eastern Uganda and Malawi (Garson, 1962) in their unusually high potash content. In the course of discussion on the composition of the Orberg rocks, Wimmenauer has brought to light a chemical analysis by A. Knop (1892) of a 'Trachytartiger Phonolith' found at the Degenmatt near the Schelingen carbonatite quarries, which has not been mentioned in the recent literature: it is quoted below in conjunction with the new analyses.

Petrography. The two specimens collected are not identical, although chemically similar. K21 consists of a close mesh of euhedral potassium feldspar crystals, 2–4 mm in length, with a strong tendency to trachytoid alignment, set in a sparse groundmass of granular to felsitic fine-grained feldspar. The larger phenocrysts (orthoclase with a moderately small 2V) are generally clear, or dusted with inclusions towards the margins, while smaller phenocrysts are more commonly clouded. The interstitial feldspar is also somewhat turbid, and locally is associated with concentrations of granular hydrated iron oxides. In places the fine-grained feldspar forms square- and rectangular-sectioned pseudomorphs, which could represent original nepheline or feldspar; certainly some of the feldspar phenocrysts are partly or wholly replaced by the felsitic feldspar of the groundmass. The only other mineral recorded is baryte, occurring as occasional aggregates in the groundmass, and penetrating some of the phenocrysts. In many respects the rock resembles the orthoclasites from Uganda; it is, however, finer grained, and might be called trachytic orthoclasite (fig. 2).

A very similar rock occurs as a xenolith, 1 cm in diameter, in the other specimen, K21A, which is more phonolitic in character. This rock is also porphyritic, but with a much higher proportion of groundmass. The phenocrysts are again euhedral potassium feldspar, both clear and slightly clouded, some of them twinned, and having a general trachytoid alignment. The fine-grained groundmass has a felsitic texture, the tiny, ill-formed laths forming a reticulate pattern within small patches, which together make a mosaic; there is little fluidal alignment, but around the xenolith flow texture is quite distinct. In the groundmass, and enclosed in some of the feldspar phenocrysts, hexagonal and rectangular pseudomorphs of nepheline, 0·5 mm across, now consist entirely of fine-grained aggregates of a colourless but turbid micaceous mineral (fig. 2). This rock was evidently a phonolite. It also contains euhedral phenocrysts of melanite zoned to pale yellow andradite, a common mineral in the Kaiserstuhl phonolites. Opaque and turbid brown iron oxides occur as amorphous granules and pseudomorphs of melanite and possibly nepheline. Elongate crystals of sphene have been replaced by calcite.

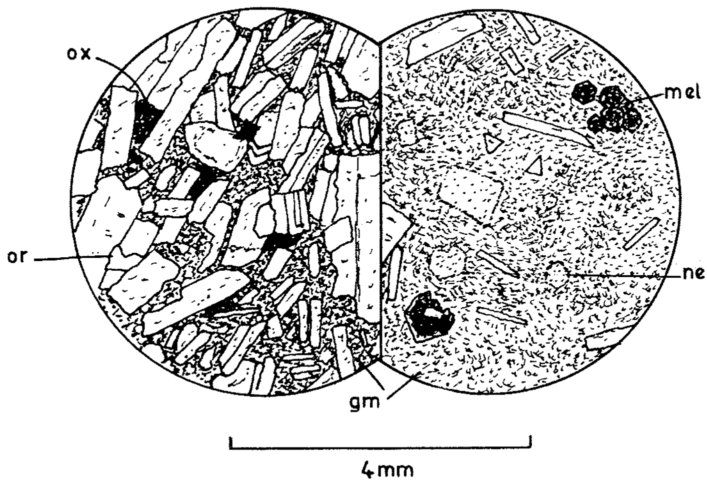

FIG. 2. (Left) trachytic orthoclasite, K21. (Right) phonolitic trachyte, K21A. Or, orthoclase; ne, micaceous pseudomorphs after nepheline; mel, melanite; gm, feldspathic groundmass; ox, hydrated iron oxides.

Chemical composition. Chemical analyses and C.I.P.W. norms of K21 and K21A and Knop's analysis are given in table I. The unusually high ratio of K_2O to Na_2O in all these rocks is notable. The presence of normative quartz and corundum suggests that alkalis may have been leached by weathering, and the hydrated iron oxides further indicate that the rocks are not entirely fresh.

In terms of $NaAlSiO_4$, $KAlSiO_4$, and SiO_2, the Kaiserstuhl rocks are closely comparable with feldspathic rocks from Uganda and Malawi (fig. 3). No significance is attached to the saturated or undersaturated character of the various rocks, particularly in view of the leaching of alkalis inferred in the Kaiserstuhl specimens.

Discussion. Despite its phonolitic affinities, K21A is chemically a trachyte; it is also highly potassic, and in this respect unlike any other phonolite in the Kaiserstuhl (Wimmenauer, 1962*b*). The presence of pseudomorphs after nepheline phenocrysts, however, indicates that originally this rock was more sodic; it is not possible to estimate more closely the original composition, but one might note the absence of relic pyroxene and suggest that it could have been anything from a normal phonolite to a phonolitic trachyte. Clearly, its present composition has been reached by metasomatism, in which nepheline was replaced by white mica and the feldspars, no doubt originally rather more sodic, became richer in potassium. It is likely that this metasomatism occurred after the emplacement of the phonolite, since the micaceous pseudomorphs of nepheline are preserved intact.

TABLE I. Chemical analyses of Kaiserstuhl trachytic rocks (anal. M. W. L. Blackley)

	K21	K21A	Knop
SiO_2	60·09	56·99	58·34
TiO_2	0·33	0·26	0·35
Al_2O_3	18·58	21·06	23·05
Fe_2O_3	3·64	2·02	2·07
FeO	0·10	0·10	—
MnO	0·09	0·06	—
MgO	0·18	0·20	tr.
CaO	0·57	1·16	0·50
Na_2O	1·21	0·92	1·79
K_2O	12·63	12·18	12·22
P_2O_5	0·08	0·05	—
H_2O tot.	2·72	4·17	1·53
BaO	—	—	0·66
	100·22	99·17	100·51

C.I.P.W. Norms	K21	K21A
qz	3·49	2·43
or	74·73	72·06
ab	10·22	7·76
an	1·95	5·12
c	2·17	4·46
hy ($MgSiO_3$)	0·45	0·50
hm	3·65	2·02
il	0·41	0·33
ap	0·20	0·13
sp	0·27	0·22

The presence of xenoliths of trachytic orthoclasite similar to K21 in the phonolite indicates that a mass of this rock was already in existence. Unlike K21A, the orthoclasite does not contain any definite relics that suggest anything other than a trachytic origin for the rock, but in view of its unusual composition, its origin is of some interest. A derivation by purely magmatic processes from tephritic or nephelinitic magma is unlikely, and, by analogy with the inferred metasomatic origin of K21A, it is suggested that metasomatism is responsible for the present composition of the orthoclasite.

The simplest explanation of the texture of K21 would be that it represents that of a normal trachyte, which became metasomatized after emplacement without destroying the trachytoid structure. Whilst the simplest may be the correct interpretation in this instance, it is worth noting that the derivation of very similar trachytic rocks in Malawi and in eastern Uganda has been shown to be more complex (Garson, 1962; Sutherland, 1965). At both these localities the development of trachytes has been traced from breccias consisting of feldspathic fragments in a fine-grained feldspar matrix. Both the trachytes and the breccias

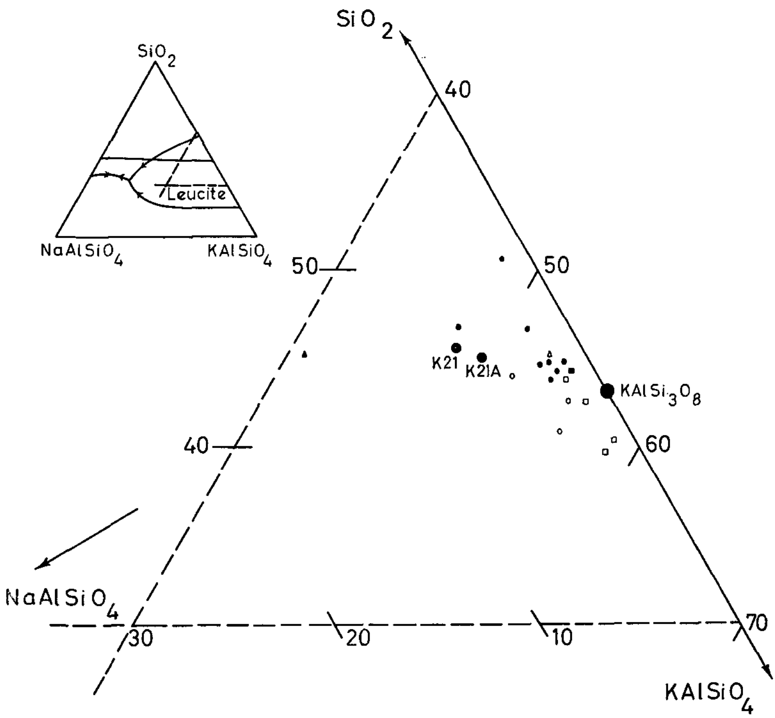

FIG. 3. Chemical composition of the Kaiserstuhl trachytes (K21 and K21A) in terms of $NaAlSiO_4$–$KAlSiO_4$–SiO_2. Other feldspathic rocks plotted are from Uganda (Sutherland, 1965) and Malawi (Garson, 1962). ○, orthoclasite; ●, potassium-trachyte; □, xenolithic trachyte; ■, feldspathic fenite breccia; △, feldspathic *fenite*; ▲, 'ferromagnesian' fenite.

occur as intrusive masses, often dyke-like, and along a single intrusion breccia is seen to grade into trachyte by the reduction of the number of fragments and the development of phenocrysts in the fine-grained groundmass. The breccias and trachytes have a uniform composition, consisting largely of potassium feldspar, and this composition is matched by potassium-feldspar rocks developed metasomatically in the country rocks close to carbonatite. It has been inferred that brecciation of the feldspathized rocks, giving rise to the intrusive breccias, represents an early stage in the mobilization of the feldspathic rocks, which eventually leads to the development of trachyte. Thus in Uganda two kinds of feldspathic rocks are recognized: those formed metasomatically, close to the carbonatite, and mobilized feldspathic rocks forming intrusions. The trachytes belong to the second group.

Of the rocks that develop by feldspathization, there are some that retain their original texture, such as the feldspathic fenite of Toror in which the fabric of the pre-existing granite-gneiss is recognizable, and there are others that develop as a mesh of interlocking crystals of orthoclase in which the earlier texture is completely obliterated (King and Sutherland, 1966, p. 92, fig. 9). There are also orthoclasites at Toror that form intrusive sheets like the trachytes, but consisting of more even-grained feldspar laths; these tend to occur close to the carbonatite, and are interpreted as trachytes that crystallized with more even grain-size, possibly under the influence of continued metasomatism adjacent to the carbonatite. The Kaiserstuhl trachytic orthoclasite closely resembles such rock.

The close association between potassium feldspathization and intrusive carbonatite has been noted increasingly in recent years (Sutherland, 1965, p. 377), and this newly described occurrence at the Kaiserstuhl confirms the common pattern. Attention should also be drawn to some potassic feldspars described by Brauns from ejected blocks in the pyroclastic rocks of the Laacher See area (in the north-western part of the Rhine fault zone). Brauns (1922) records feldspar from 'Calcitsyenit' with K_2O 13·88, Na_2O 1·53 %, and in the same work, Frechen has pointed out to me descriptions by Brauns of sanidine crystals with between 11·61 and 12·71 % K_2O and between 2·22 and 3·13 % Na_2O. Again there is an association with carbonatite, for although the Laacher See suite is entirely volcanic (tephrites, nephelinites, phonolites, and associated tuffs, with late trachytic pumice), ejected blocks include in addition more deep-seated types such as feldspathoidal syenites, alkali metasomatized country rock, and carbonatite (references to the literature can be found in Frechen, 1962).

The reason for the association between potassium feldspathization and emplacement of carbonatite is still not known. Von Eckermann (1948) has suggested, on the basis of chemical calculations, that the carbonatite at Alnö was primarily potassic at the time of its emplacement; but chemical analyses of fresh carbonatite lava at Oldoinyo Lengai (Dawson, 1962) show it to contain more soda (29 %) than potash

(7 %) or lime (12 %). Nevertheless, a study of the development of the various alkaline rocks in the complexes of eastern Uganda (Sutherland, 1966; King and Sutherland, 1966) clearly indicates that the residuum formed in the crystallization of ijolite consists of potassium feldspar, sometimes associated with the carbonate minerals cancrinite and calcite. At Budeda, for example, the feldspar occurs interstitially as clear 'pools' in patches in the ijolite. More extensive feldspathization of the ijolite is associated with the development of cancrinite, a phenomenon that is also observed at Napak. The potassium-feldspar–carbonate paragenesis is therefore regarded as essentially a residuum derived by the crystallization of the alkaline silicate rocks. It still remains a problem to explain why the feldspar should be so potassic, when the associated alkaline rocks and even the carbonatite itself are predominantly sodic.

Acknowledgements. The author greatly appreciates the courtesy and kindness shown by Professor Pfannenstiel and other members of the Geological Institute of the University of Freiburg, and by Professor Wimmenauer of the Geological Survey, in arranging visits to the Kaiserstuhl. The financial assistance provided by the British Council is gratefully acknowledged.

References

BRAUNS (R.), 1922. Die Mineralien der niederrheinischen Vulkangebiete. Stuttgart.
DAWSON (J. B.), 1962. Nature, vol. 195, p. 1075.
ECKERMANN (H. VON), 1948. Sver. geol. undersök, no. 36.
FRECHEN (J.), 1962. Führer zu vulkanologisch-petrographischen Exkursionen. Stuttgart.
GARSON (M. S.), 1962. Mem. Geol. Surv. Nyasaland, no. 2.
KING (B. C.) and SUTHERLAND (D. S.), 1966 in Carbonatites, ed. TUTTLE (O. F.) and GITTINS (J.). John Wiley and Sons, New York.
KNOP (A.), 1892. [Der Kaiserstuhl im Breisgau. Eine naturwissenschaftliche Studie. Leipzig. 534 pp.]
SUTHERLAND (D. S.), 1965. Min. Mag., vol. 35, p. 363.
—— 1966. Ph.D. thesis, Univ. London.
WAMBEKE (L. VAN) *et al.*, 1964. Les roches alcalines et les carbonatites du Kaiserstuhl. Euratom publication, EUR. 1827 d, f, e. Brussels.
WIMMENAUER (W.), 1957. Geological map of Kaiserstuhl. Geol. Landesamt in Baden-Württemberg. (Accompanies 1959*a*).
—— 1959*a*. Geologische Exkursionskarte des Kaiserstuhls. Freiburg i. Br.
—— 1959*b*. Neues Jahrb. Min., Abh., vol. 93, p. 133.
—— 1959*c*. Fortschr. Min., vol. 37, p. 67.
—— 1962*a*. Neues Jahrb. Min., Monatshefte, vol. 1, p. 1.
—— 1962*b*. Neues Jahrb. Min., Abh., vol. 98, p. 367.
—— 1963. *Ibid.*, vol. 99, p. 231.
—— 1966. in Carbonatites, ed. TUTTLE (O. F.) and GITTINS (J.). John Wiley and Sons, New York.

[*Manuscript received 4 February 1967*]