and fabric orientation in the immediate vicinity of pre-tectonic porphyroblasts. Pressure fringes may therefore provide useful information in attempting to understand how truncation relationships are formed.

(ii) Sinha Roy's second conclusion accords with our discussion (pp. 476–8).

(iii) The third conclusion endorses our assertion (pp. 471 and 476) that in cases of multiple deformation a truncation relationship does not necessarily imply porphyroblast growth subsequent to all deformation and crystallization. We do not doubt that porphyroblasts embedded in a matrix subjected to strong deformation 'tend to be moulded in the matrix'. Nor do we doubt, with reference to the examples quoted by Sinha Roy, that strained porphyroblasts around which *Se* is deflected must be earlier than a deformation event. Where such criteria exist misinterpretation is difficult. But where unstrained porphyroblasts truncate *Se*, then care must be taken and additional criteria sought in order to decide which if any of the deformation events the porphyroblasts postdate. To say that 'such truncations need not be misinterpreted by relating them to the later event in reference to which the porphyroblasts are pre-tectonic' is to miss our point.

Reference additional to the above

Williams, P. F. 1972. 'Pressure shadow' structures in foliated rocks from Bermagui, New South Wales. *J. geol. Soc. Aust.* **18**, 371–7.

Department of Geology
University of Nottingham
Nottingham NG7 2RD

C. C. FERGUSON

Grant Institute of Geology
University of Edinburgh
Edinburgh EH9 3JW

B. HARTE

11th July 1976

The role of CO_2 in alkali rock genesis

SIR, – Rock (1976) has collected a convincing volume of data from natural occurrences which seems to indicate antipathy in the association of carbonatite with igneous rocks which contain calcic plagioclase. He suggests that this antipathy may be masked to the casual observer if it is not recognized that different ages of intrusion may occur at a single centre, but he chooses to illustrate this point by considering the Damaraland Province in South West Africa (Martin, Mathias & Simpson, 1960).

Rock (p. 104) refers to 'tholeiitic Bushveld gabbros' in relation to the Damaraland Province which are presumably those of the Bushveld Igneous Complex some 1300 km to the SE and not associated with the Damaraland alkaline and carbonatitic rocks at all. The Damaraland intrusions occur within high grade metasedimentary rocks and associated granitic rocks of the Pan-African Damara Mobile Belt. Perhaps the confusion arose through the misidentification of the Spitzkop intrusion (a granite pluton) of the Damaraland province with the well known Spitzkop carbonatite complex in the Transvaal, which is indeed intrusive into gabbros of the Bushveld Complex.

In the same discussion Rock seems to imply that all the other southern Africa carbonatite occurrences are part of the Damaraland Province, including the well known Palabora complex which lies some 1400 km to the SE. This generalization can only confuse the point he is attempting to clarify.

There are several features of other southern African carbonatites which are at variance with data assembled by Rock. Modern interpretation (Verwoerd, 1967) indicates that the carbonatite at Kruidfontein is *not* a xenolith of carbonate sedimentary rock but is magmatic in origin and is therefore one instance where carbonatite and basaltic rocks do occur intimately related. The entry for this occurrence should therefore be deleted from Table 3.

Small inclusions of hortonolite monzonite (of uncertain origin) occur in the Okorusus [*sic*] intrusion in Damaraland and fayalite diorite and theralite are not associated with this carbonatite. As has been mentioned this intrusion is geographically unrelated to the Bushveld Complex and the entry in Table 3 is therefore erroneous.

The entry of Swartbooisdrift as a gabbro complex in Table 2 is also incorrect. Swartbooisdrift is the location of a group of alkaline and carbonatitic rocks which have been dated at 749 Ma (Verwoerd, 1967). These rocks are intrusive into basic rocks of the Kunene anorthosite complex which has a minimum age of

1260±90 Ma (Simpson & Otto, 1960). Clearly the alkaline/carbonatite rocks and basic rocks are unrelated and Swartbooisdrift is a good example of a fortuitous association of these rock types and is best included in Table 3.

References

Martin, H., Mathias, M. & Simpson, E. S. W. 1960. The Damaraland sub-volcanic ring complexes in S.W. Africa. *Int. Geol. Cong. 21st session* **13**, 156–74.

Rock, N. M. S. 1976. The role of CO_2 in alkali rock genesis. *Geol. Mag.* **113**, 97–113.

Simpson, E. S. W. & Otto, J. D. T. 1960. On the Precambrian anorthosite mass of southern Angola. *Int. Geol. Cong. 21st session* **31**, 216–27.

Verwoerd, W. J. 1967. *The carbonatites of South Africa and South West Africa.* Handbook 6, Geol. Surv. Dep. Min. S. Afr. 452 pp.

J. S. MARSH

Department of Geology
Rhodes University
P.O. Box 94
Grahamstown 6140
South Africa
21*st June* 1976

SIR, – I thank Dr Marsh for his constructive criticisms of my illustration of the proposed carbonatite-plagioclase antipathy from southern African alkaline rocks. Effectively, his criticisms revolve around my somewhat liberal use of the term 'province' which perhaps implied closer temporal and spatial relations than actually exist between the complexes discussed. As indicated (Rock, 1976, p. 97) the paper was merely a preliminary report, an ultra-condensation of a very large body of evidence; Dr Marsh may with some justification feel that precision has been sacrificed in the interests of condensation, but I hope he will accept my case in the light of further details from the references he himself cites, which I feel largely answer his criticisms. I welcome especially the opportunity for greater amplification of some equivocal cases whose data I consider entirely compatible with the antipathy even though they may have appeared contentious in condensed form. Evidence and arguments are presented much more fully, and I hope without the confusions pinpointed by Dr Marsh, in my unpublished thesis.

Among the most confusing complexes are Kruidfontein and Tweerivier which, following Heinrich (1966), I considered together in Table 5 because of their proximity and closely-related problems. Tweerivier comprises a large carbonate body associated with gabbros, anorthosites and granites, while Kruidfontein is a diatreme with concentric basaltic, intermediate and acid lavas and pyroclasts surrounding a caldera-like depression filled with carbonate-rich rocks. Both carbonates were regarded by Fockema (1949, 1952) as Transvaal dolomite from the presence of conformable ironstones, baking at contacts and abundant tremolite, etc., but by Verwoerd (1967) as 'carbonatites' on the basis of trace elements and reinterpreted field relations. Lacking first-hand knowledge, I could not eliminate Fockema's interpretation, implying that both areas are fortuitous gabbro(basalt)/limestone associations, from Table 5. Fortunately, however, Verwoerd's own discussion confirms them as entirely fortuitous spatial associations, though this time of Bushveld gabbros with possible carbonatites. For Tweerivier, Verwoerd states (p. 97): 'no genetic significance may be attached to the fact that gabbro occurs together with sovite', for he argues carefully that the bronzite gabbros are merely xenoliths of Bushveld material incorporated in and fenitized by a later carbonatite plug (pp. 96–8). Kruidfontein is less obvious, for Verwoerd considers it to be 'unique in that the full sequence from basic through intermediate to acid silicate rocks is present with an additional hydrothermal phase corresponding to carbonatite' (p. 169).

This is misleading on two grounds: (*a*) in accordance with Heinrich's (1966) generally accepted recommendations my paper confined the term *carbonatite* to *magmatic* rocks (p. 101); no true carbonatites with high Ba or Sr outcrop at Kruidfontein – Verwoerd regards the partly stratified 'metabeforsite' of the central caldera entirely as a *hydrothermally carbonatized* tuff deposit (pp. 156 and 167–9); his use of the terms sovite, beforsite and carbonatite would now be considered incorrect. Indeed, in stating so emphatically that 'modern interpretation (Verwoerd, 1967) indicates that the carbonatite...is magmatic in origin' Dr Marsh seems

himself to have fallen into the very interpretive trap in question here; Verwoerd states nothing of the sort, even though his terminology to current readers might *imply* this. (*b*) 'Undersaturated alkaline rocks. . . are conspicuously absent', (p. 169) and the remaining rhyolites, microsyenites (gauteites), trachytes and rhyolitic ignimbrites are quite unlike typical carbonatite associates. Although the absence of fresh analyses makes interpretation difficult, petrography (e.g. orthopyroxene) and available data confirm the oversaturated nature of the lava-suite; I inferred tholeiitic affinities (Table 3) but calk-alkaline or transitional alkaline (i.e. hypersthene-normative alkali basalt parent) are equally plausible. But whichever is correct, and however we regard the carbonates, the latter *cannot* be genetically related to the volcanics – only true undersaturated magmas can give rise to carbonatites (Wyllie, 1966 and p. 101). For Kruidfontein to be unique as Verwoerd suggests, and thus to violate the antipathy, both magmatic carbonatites and undersaturated alkaline basaltic rocks have to be postulated at depth – i.e. the violation has itself to be postulated! The imagination is less stretched by regarding Kruidfontein as a basaltic suite erupted from a vent which was later used as a line of weakness by hydrothermal carbonate solutions – effectively Verwoerd's own interpretation.

Far from requiring deletion from Table 3, then, Kruidfontein and Tweerivier admirably illustrate the confusions which may mask the antipathy, as hinted on p. 104; carbonatites intrude unrelated gabbros or basalts and fenitize them so as to conceal their different origins, while the carbonatites themselves are confused with both sedimentary limestones and hydrothermal carbonates of low temperature origin.

Dr Marsh's criticisms over the inclusion of Spitskop & Palabora on p. 104 and in Table 2 are neutralized by substituting 'southern Africa' for 'Damaraland province'; the loose usage of 'province' in Table 2 is already implied by the inclusion of N America and Europe – clearly the many complexes in these regions are of widely differing ages.

I regard my inference (Table 3) concerning Okorusus as probably justified although I accept Dr Marsh's criticism in that condensation has made it misleading; in condensing I equated 'hortonolite monzonite' with 'fayalite diorite' since such types must be close in composition, inferring then that the Okorusus hortonolite monzonite inclusions might, like the Spitskop fayalite diorite, be fenitized gabbros. My further identification of this parental gabbro as Bushveld was, on reflection, suspicious and unnecessary, but does not affect the present arguments: I wished merely to indicate a link between the two complexes and suggest that the Okorusus incusions could be genetically unrelated to the carbonatites, in the absence of any alternative suggestions. Perhaps at Okorusus the gabbros were related to those of Messum or Okonjeje rather than to the Bushveld complex.

I readily accept then that such a highly condensed account may generate confusion, particularly if an attempt is made to extrapolate back to the original information as Dr Marsh has done, but maintain that the facts presented hold water as a preliminary account. Further, I would not accept any implication that the condensation has acted to conceal loopholes in the hypothesis itself, because the full data I have collected seem miraculously to show almost none in the first place.

References (addition to the above)

Fockema, R. A. P. 1949. An occurrence of alkaline and acid lavas and volcanic breccias on the farm Kruidfontein 147, Rustenburg district. *Trans. geol. Soc. S. Africa* **5**, 205–29.

Fockema, R. A. P. 1952. The geology of the area around the confluence of the Elands and Crocodile Rivers. *Trans. geol. Soc. S. Africa* **55**, 155–74.

Heinrich, E. W. 1966. *The Geology of Carbonatites*. Rand McNally, Chicago.

Wyllie, P. J. 1966. Experimental data bearing on the petrological links between kimberlites and carbonatites. *I.M.A. Vol. 4th general meeting, India*, 67–82.

N. M. S. ROCK

Department of Mineralogy and Petrology
Downing Place
Cambridge
9th September 1976