

*Silica percentage as a factor in igneous-rock
classification.*

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IN previous editions of Hatch's 'Petrology of the igneous rocks' including the last two, for the revision of which the writer was largely responsible, historical precedent was followed and the main lines of classification were based on variation in the silica percentage. In preparing for the new post-war edition considerable thought has been given to this matter. The weakness of the scheme has become increasingly apparent to the writer, and it is now obvious that no juggling with the selected ranges of silica percentage chosen to delimit the 'acid', 'intermediate', and 'basic' categories can result in a workable, logical scheme. Silica percentage as a basis of rock classification must be abandoned for the reasons discussed below.

The value of the terms 'acid' and 'basic' as applied to rocks is not in question. They conjure up a most useful mental picture involving strong contrasts. On the one hand, the typical acid rock is light coloured, of low specific gravity, and deficient in ferromagnesian silicates. By contrast, the basic rock has a different mineral assemblage, it is dark coloured, of high specific gravity, and rich in ferromagnesian silicates. The commonly accepted mineralogical criterion of acidity is the amount of *free silica* (quartz) in the rock; but acidity is a purely chemical conception, depending on the balance between the acid and basic radicles—the whole of them, not a part only. In typical granites, however, of the total silica, only about one-quarter is free quartz, three-quarters is combined.

As we pass from the basic into the acid rocks, the incoming of quartz marks a significant change in the chemical constitution of the rocks: it shows that the condition of over-saturation with silica has been achieved. Theoretically this should provide one of the fundamental boundaries between rock groups, as Shand has long urged; but actually the solution is not as easy as it appears at first sight. Many intermediate and some basic rocks carry small quantities of quartz tucked away inconspicuously between the essential components. Such rocks are de-

finitely over-saturated, but they are just as clearly not 'acid'. 'Over-saturated' is not synonymous with 'acid'; and in rock-classification *the degree of over-saturation* is more important than the mere fact of over-saturation. As regards mineral composition, all petrologists are agreed that no rock should be termed granite unless quartz occurs in sufficient amount to rank as an *essential* constituent. They agree, further, that a certain amount of latitude is necessary when defining syenite, diorite, norite, gabbro, dolerite, &c., to cover those rocks which, in all essentials fall into one or other of these categories, though they do contain *accessory* quartz.

The immediate problem is to define the boundary between the 'acid' granites, adamellites, and granodiorites on the one hand, and the 'intermediate' syenites, syenodiorites (monzonites), and diorites on the other. Evidently the first requirement must be to reach agreement on the definitions of 'essential' and 'accessory'. Although this is a matter of prime importance, agreement has not yet been reached. Johannsen¹ in his scheme of classification allows a latitude of 5 % free quartz, while Shand² is more generous and allows 10 %. Provided it is inexpedient to draw the boundary exactly where discernible quartz first appears, it is of small moment whether the higher or the lower figure is chosen; but it appears to us that there is a good deal to be said in favour of 10 %. The well-known Dresden syenite ('plauenite' of some writers) enjoys a world-wide reputation (which it does not really deserve) of being typical of its kind. It is very widely used for teaching purposes, and many generations of geologists have based their impressions of the typical syenite on this rock, in spite of the fact that much of the apparent orthoclase is seen under the microscope to be red-stained oligoclase in the form of Carlsbad-albite twins. Apart from this, however, the rock is definitely over-saturated, the amount of free quartz varying from 5 or 6 to as much as 12 % (fig. 1, S' to S"). Therefore some of the Dresden 'syenite' cannot be admitted into this category in any case: it contains more quartz than can be allowed in a syenite and this facies is granitic (actually adamellite). If Johannsen's limit of 5 % were accepted none of the Dresden 'syenite' could be classed as syenite, it would all be granite. This suggests that, as it seems desirable to leave some of this classical rock in the position it has occupied since Werner's time, the limit between essential

¹ A. Johannsen, *A descriptive petrography of the igneous rocks*. Chicago, 1937, vol. 3, p. 4. [M.A. 6-483.]

² S. J. Shand, *Eruptive rocks*. 3rd edit., London and New York, 1947, p. 370. M.A. 10-305.]

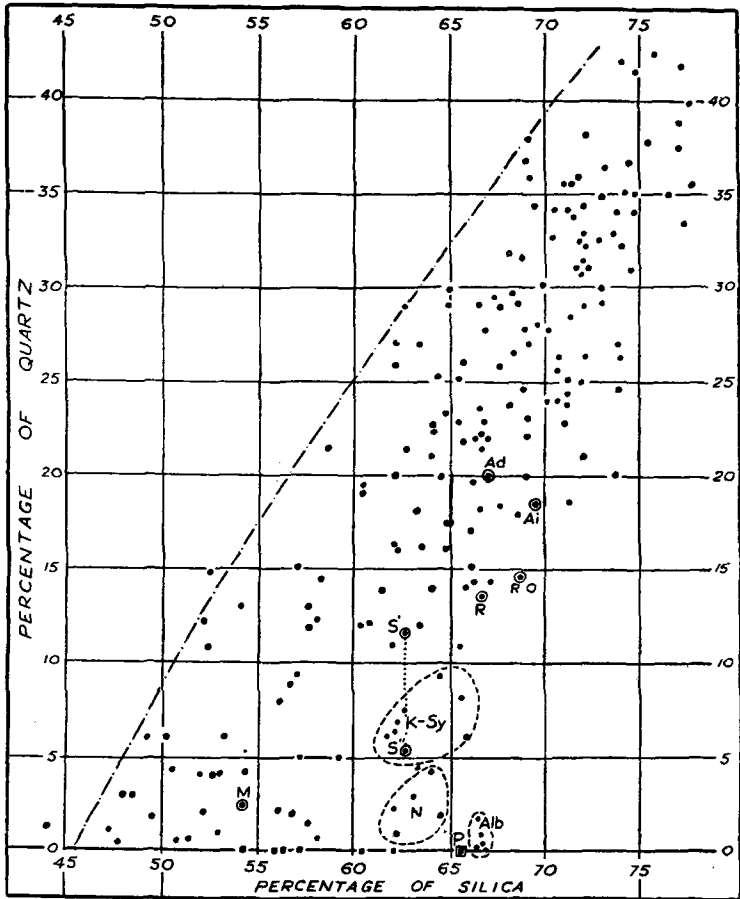


FIG. 1. Plot of the silica percentage and quartz content of certain acid and intermediate igneous rocks. Alb, albitite field; P, perthosite; N, nordmarkite field; M, type monzonite; K-Sy, potassic syenites (kaligranites of Johannsen) S'-S'', 'Dresden syenite'; R, rockallite; R.O, riebeckite-orthophyre (Tyrrell); Ai, ailsite (riebeckite-microgranite, Tyrrell); Ad, centre-point of adamellite field. The dash-dot line indicates the upper limit of free quartz.

and accessory, as applied to quartz, should be 10%. It follows that no rock carrying less than this amount of quartz should be called granite; and conversely, no syenite, syenodiorite, or diorite may contain more than 10%.

The problem resolves itself, therefore, into selecting a silica percentage which will include in the granites all those rocks containing 10% or

more of quartz, and at the same time will exclude therefrom all those rocks which contain less than this amount. If the amount of quartz were proportional to the total silica in igneous rocks, the solution would be easy; but there is no such simple relationship, and a solution is impossible.

The publication of Johannsen's encyclopaedic 'Descriptive petrography' has clarified the problem considerably by bringing together and classifying large numbers of first-class analyses, with the corresponding modes. In order to examine the relationship between silica percentage and quartz content, a 'plot' has been made of quartz-bearing igneous rocks recorded by Johannsen, for which analyses and modes are given (fig. 1). The rock-types plotted comprise all kinds of granites including adamellites and granodiorites as well as quartz-bearing syenites, monzonites, diorites, gabbros, and norites. From the diagram two important facts emerge: firstly, rocks containing identically the same amount of quartz may vary in total silica by 15 % or more; and secondly, for a constant silica percentage the amount of quartz may vary from zero to as much as 35 %. The causes of this large variation are sufficiently interesting to warrant examination. In this connexion the group of highly alkaline nearly monomineralic syenites which includes perthosite (P in fig. 1), albitite (Alb), and the hypothetical 'orthoclase-site', are important. In the members of this group, the whole of the silica, which ranges from about 66 % to nearly 69 %, is combined. But, as the diagram shows, within this range of silica percentage there are quartz-bearing syenites, 'kaligranites' (Johannsen), adamellites, and granodiorites in variety, some with a quartz content as high as 35 %. Of the various silicates which go to make up these rocks, the alkali-felspars, orthoclase and albite, contain most combined silica, and therefore within this limited silica range, the rock-types richest in these minerals will be poorest in free quartz, and may contain none. There is no question as to the systematic position of these latter rocks: they are syenites by virtue of their mineral content, and in spite of their high silica percentage. If now some of the alkali-felspar is replaced by plagioclase appropriate to these rocks, the combined silica falls, and some free quartz must be added to bring the total silica back to the initial value. A simple calculation shows that with a constant silica percentage of 66, the complete substitution of oligoclase for orthoclase would give a leucotonalite, consisting of 90 % plagioclase and 10 % quartz. But the incoming of the basic silicates, hornblende and especially biotite, produce the same kind of effect though on a much more important scale. In rocks

of these kinds, hornblende contains approximately 48 %, but biotite only 35.5 % of combined silica.¹ It follows that within the 66–69 % total silica range, those rocks at the top of the column are richest in biotite, plagioclase, and free quartz, while those at the bottom are correspondingly poor in these constituents, but rich in alkali-felspars.

Reverting now to the main problem, it is obvious from the diagram that to include among the granites all those igneous rocks with 10 % or more of quartz, the line would have to be drawn at about 52 % total silica. To exclude from the granite category all those quartz-bearing igneous rocks with less than 10 % of this mineral would necessitate drawing the line at about 69 % total silica. Nothing can bring these two lines closer together, and they are equally unsuitable. It is evident that *division on a silica-percentage basis results in bringing together those rocks which it is desired to separate*. The only possible way of retaining this basis of classification would be to devise a sliding scale, with three variables: amount of free silica, ratio of alkali-felspar to plagioclase, and content of coloured silicates. Obviously this would be so complicated as to defeat its own ends: it would be wholly unworkable. Regretfully, therefore, the conclusion is forced upon us that silica percentage must go.

The writer places on record his gratitude to his son for helpful discussion during the preparation of this paper, and for making a fair copy of the diagram.

¹ A. Johannsen, loc. cit., vol. 2, p. 151.