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Phil. Trans. R. Soc. Lond. A 1971 **268**, 403-408
doi: 10.1098/rsta.1971.0003

Phil. Trans. Roy. Soc. Lond. A. **268**, 403–408 (1971) [403]
Printed in Great Britain

Petrology of ultrabasic rocks from rift zones of the Mid-Indian Ocean Ridge

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[Plate 2]

Ultrabasic rocks from the Mid-Indian Ocean Ridge and peridotites of the alpine type have similar petrographic characteristics. A petrochemical comparison of these rocks shows that oceanic peridotites are enriched in SiO_2 and normative hypersthene.

The direction of the development of the composition of ultrabasic rocks after separation of different amounts of basalt from pyrolites of oceanic and alpine type ultrabasic rocks was obtained by calculation. Combination of these data with experimental melting diagrams shows that alpine type ultrabasic rocks melt at higher temperatures than oceanic ultrabasic rocks.

On geological and petrochemical grounds we think that the ultrabasic rocks which outcrop in the rift zones of the Mid-Indian Ocean Ridge are a specific formation. This formation consists of slighty differentiated pyrolites of the oceanic type.

Study of the world's oceans for the last several years shows that the ultrabasic rocks are not so rare on the ocean bottom, especially in the rift zones of the mid-oceanic ridges. We now have data about the disposition and petrographic and chemical composition of these rocks by Shand (1949, see Hess 1964), Cann & Vine (1966), Cann & Funnell (1967), Hekinian (1968), Bonatti (1968), and other scientists.

This paper contains some aspects of the petrology of ultrabasic rocks from the Mid-Indian Ocean Ridge in comparison with peridotites of the alpine type in connexion with the upper mantle.

We have a good collection of crystalline rocks from several regions of the Mid-Indian Ocean Ridge which were sampled by the 36th expedition of the R.V. *Vitiaz* 4 years ago, and by the second expedition of the R.V. *Academic Kurchatov* 2 years ago (Udintsev 1965; Aksenov & Udintsev 1967).

This collection consists of more than 500 large samples and is more than 1.5 Mg (tonnes) in total mass. Ultrabasic rocks make up about 50 % of this collection.

Geologically these rocks are associated with gabbro, dykes of dolerite and products of its greenstone alterations. This combination of rocks is the first of two main combinations, which outcrop in the oceanic ridges. The second combination consists of fresh basalts and pillow lava which are represented by undifferentiated primary basaltic melts, mainly tholeiitic magmas. The first combination is probably the older.

The latest expedition of R.V. *Academic Kurchatov*, which finished on 1 November 1969 discovered two similar complexes of crystalline rocks in two regions of the Mid-Atlantic Ridge. It is moreover found that ultrabasic rocks associate with gabbro, dolerites and greenstones also in the first complex.

Ultrabasic rocks of the Mid-Indian Ocean and Mid-Atlantic Ridges have petrographical characteristics similar to peridotites of the alpine type on continents. Among them harzburgite and to a lesser extent lherzolite also predominate. Dunites and pyroxenites are almost absent.

All rocks have features which show the possibilities of residual melt crystallization and of metasomatism.

Figure 1, plate 2, shows the typical texture of slightly serpentinized peridotite in thin section. The area of this section is about 15 mm^2. This rock consists of residuals of olivine and pyroxene. It is shown that there are no specific properties in these rocks. Very similar rocks occur in the Urals, and in Cornwall, etc.

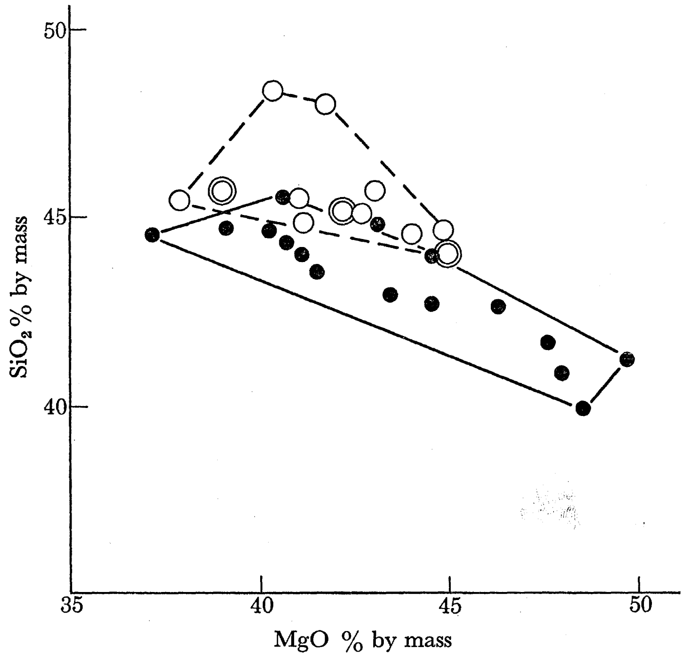

Figure 3. Correlation between MgO and SiO_2 (% by mass) in different types of ultrabasic rocks. ●, peridotites of alpine type from different regions (average); ○, peridotites from M.A.R. (see text); ◎, main types of peridotites from Mid-Indian Ocean Ridge (average).

Figure 2, plate 2, shows a totally serpentinized peridotite. It consists of lizardite, which has replaced olivine, and bastite, which has replaced pyroxenes. The second stage of serpentinization is represented by coatings and veins of antigorite, which can be seen in figure 2.

We have made so far 50 petrochemical analyses for peridotites from five sections of the Mid-Indian Ocean Ridge. We used also ten recently published analyses of peridotites from the M.A.R. made by Cann & Funnell (1967), Hess (1964), Hekinian (1968) and Bonatti (1968).

All these data were used for petrochemical comparison of peridotites of oceanic and alpine type and of peridotite nodules in basalts and kimberlites. The comparison was made by plotting the magnesium content against the concentration of each petrochemical component, and magnesium against norms of minerals by Niggli's method.

We give here only two diagrams, which illustrate this comparison and have significance for this article. The tables of all useful analyses were published by Vinogradov, Udintsev, Dmitriev *et al.* (1969) and will shortly appear in the monograph *The Sea*, vol. 4.

Figure 3 shows the correlation between magnesium and silica. The black points mark the average composition of peridotites of alpine type and peridotite nodules from different regions: the Central and Polar Ural, the Caucasus, Central Asia, Cornwall, etc. (see legend for figure 3). About 1000 published analyses were used for it. Here we also have used the average

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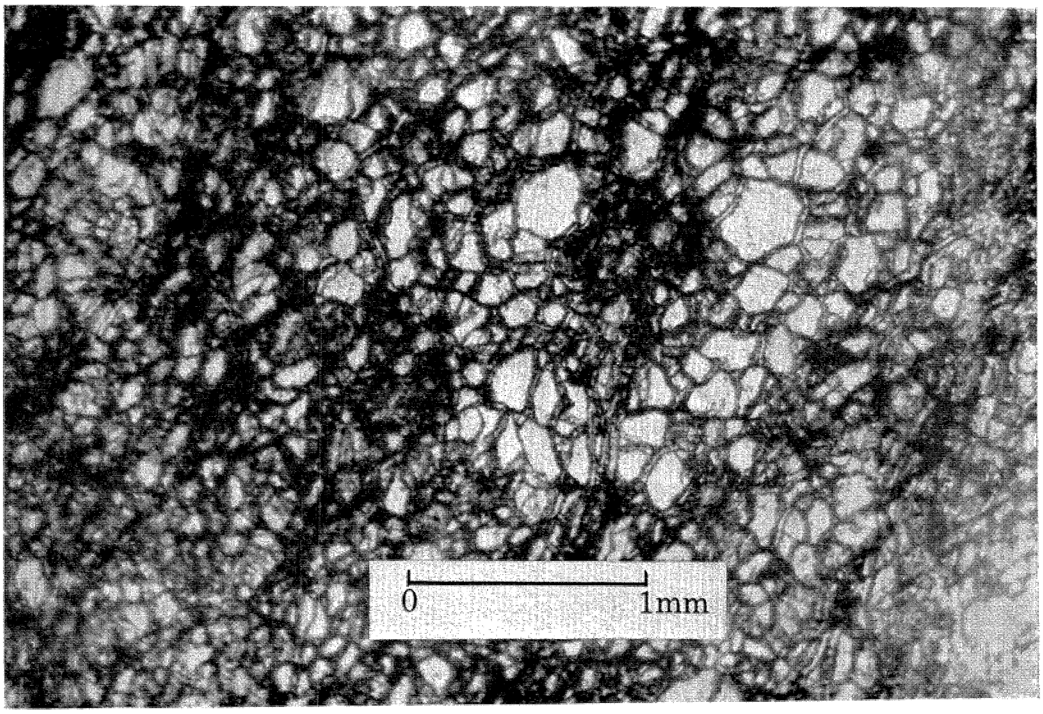

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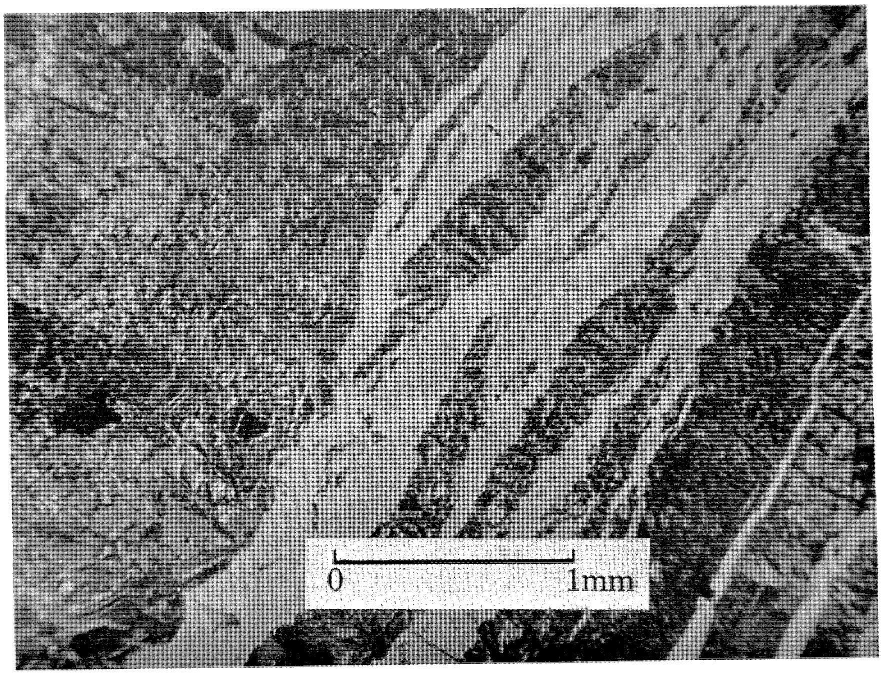

FIGURE 1. A thin section of slightly serpentinized peridotite. It is possible to see relics of olivine (white). No crossed nicols.

FIGURE 2. A thin section of the second stage of serpentinization of peridotite. Thin veins of antigorite cut the lizardite. Crossed nicols.

petrochemical composition of ultrabasic rocks riven by Daly (in Zavaritsky 1950; Nockolds 1954). The empty circles mark oceanic peridotites; double circles mark the average composition of main peridotite types from the Mid-Indooceanic Ridge. We can see that oceanic peridotites are enriched in silica in comparison with peridotites of the alpine type.

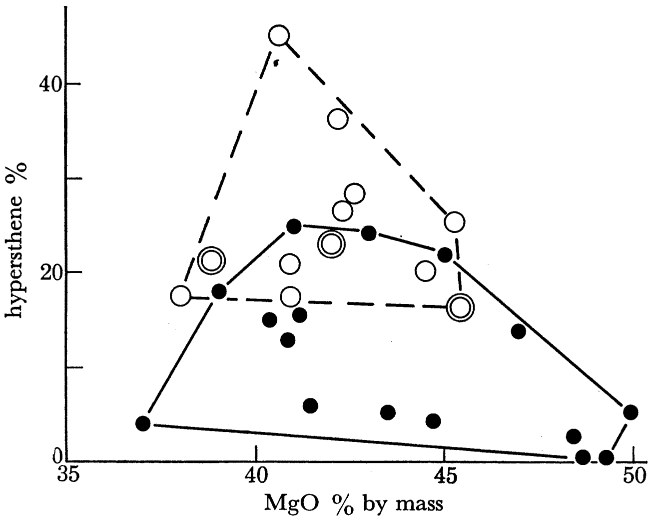

Figure 4. Correlation between MgO and hypersthene (molecular norms by Niggli) in different types of ultrabasic rocks. For explanation of symbols see figure 3.

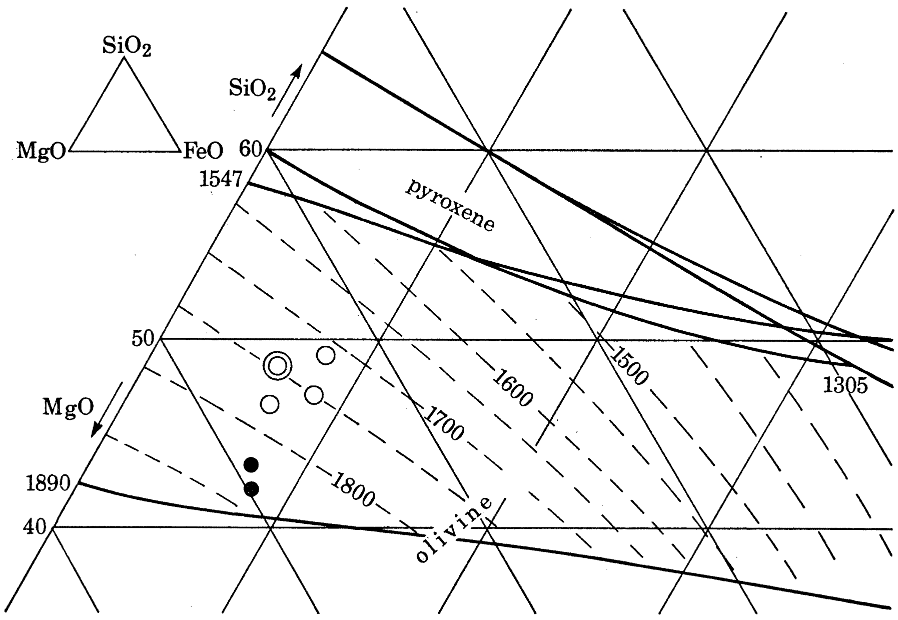

Figure 5. Part of the melting system: MgO–SiO_2–FeO by Bowen & Schairer (1935). For explanation of symbols see figure 3.

Figure 4 shows the correlation between magnesium and the concentration of mineralogical hypersthene norms by Niggli's method for the same rocks. Here we can see that oceanic peridotites are enriched in hypersthene in comparison with peridotites of the alpine type and nodules in basalts and kimberlites.

All these data have led us to believe that the Mid-Indian and Mid-Atlantic Ridges have a similar construction, and their ultrabasic rocks were formed by similar processes which differ from those under continents.

We obtained an idea about this process, after the study of rocks from mid-oceanic ridges and the utilization of numerous published works devoted to the upper mantle problem. Figure 5 shows part of Bowen's & Schairer's (1935) diagram of the melting system, silica, magnesium and iron. The composition of typical oceanic and alpine peridotites are plotted on this diagram. It is shown that oceanic peridotites have a lower melting temperature than alpine peridotites and that the concentration of iron cannot influence the melting temperature of these kinds of rocks.

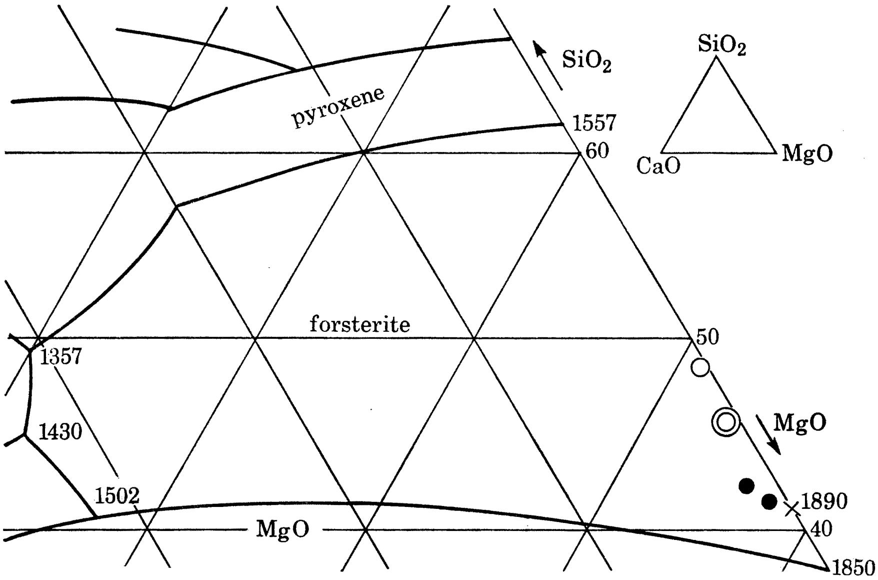

FIGURE 6. Part of the melting system: $MgO–SiO_2–CaO$ by Ferguson & Mervin (1919). For explanation of symbols see figure 3.

Figure 6 shows part of the diagram of the melting system: silica, magnesium and calcium oxide by Ferguson & Mervin (1919), for the same composition of rocks. This diagram also shows that oceanic peridotites have a low melting temperature in comparison with peridotites of the alpine type.

The development trend of the composition of ultrabasic rocks after separation of different amounts of basaltic melt from the primary pyrolite was determined for oceanic series of ultrabasic rocks and for those of the alpine type by way of calculation. A similar calculation method has been used by many petrologists, for example by Green & Ringwood (1963) for the determination of hypothetical pyrolite composition. But they obtained their pyrolite by addition of dunite and basalt composition.

Our operation includes successive subtraction of different amounts of real basalt from real lherzolite which occur under concrete geological conditions. In this case we believe that lherzolite may serve as initial material for producing different series of residual ultrabasic rocks because the composition of lherzolite is close to the pyrolite of Green & Ringwood. Of course, these series cannot include pyroxenites or troctolites, because these rocks are absent in oceanic formations of ultrabasic rocks and in those of the alpine type. It is known, too, that pyroxenites and troctolites are intermediate rocks, between ultrabasic and basic ones, and were formed by differential crystallization of basaltic melt in stratymorphic formation. After this operation we obtained several complementary series, which coincide with real series of ultrabasic rocks from different regions. We can see this series in figure 7. This is a part of Bowen's (1915) system: diopside, forsterite and silica, which was modernized by Kushiro & Schairer (1963). Each line shows the development trend of different peridotite types. Here nodules of peridotites in kimberlites are lying in an extreme left position. The average composition of peridotites given by Daly lies near this position. Oceanic peridotites occupy a position at the extreme right lower corner. Between them are disposed different series of peridotites of the alpine type. The position of the melting isotherms is only approximately marked, but we can see that the oceanic series lies in the low-temperature region in comparison with the alpine type and especially with peridotite nodules. We can also see that the series of peridotites of the alpine type begins near the pyrolite of Green & Ringwood, but that the series of oceanic peridotites begins from different pyrolite types which contain more silica and have a lower melting temperature.

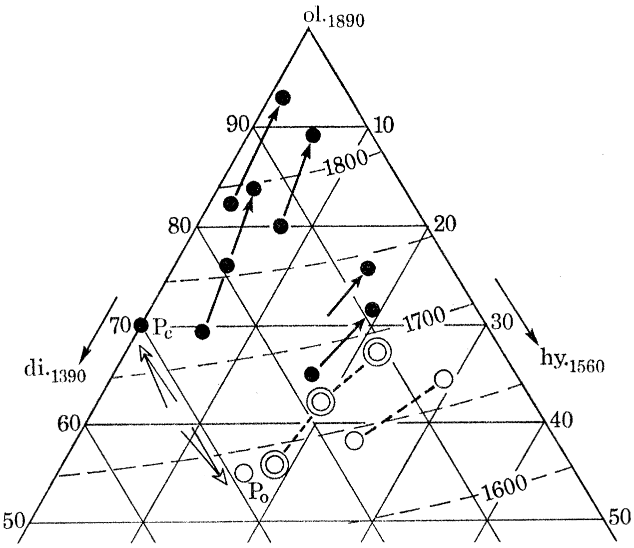

Figure 7. The complementary series of the different types of the ultrabasic rocks in part of the melting system: olivine–diopside–SiO_2 by Bowen (1919). For explanation of symbols see figure 3. $\mathrm{P_c}$, the pyrolite of Green & Ringwood (1963); $\mathrm{P_o}$, the hypothetical pyrolite of oceanic type.

Earlier it was supposed that pyrolites under continents have different composition. It is possible that plagioclasic lherzolites from rift zones of mid-oceanic ridges are residuals of oceanic pyrolite.

In development of this idea it may be supposed that the greater the differentiation of the upper mantle and the amounts of fused basalts, the thicker is the Earth's crust.

This assumption is confirmed by the following. If we suppose that the oceanic mantle has an ultrabasic composition there are not very favourable conditions for magmatic differentiation, because the thin oceanic crust cannot serve as a reliable heat protection and cannot create high pressure, which is necessary for the usual magmatic process. It also has been confirmed by the low scale of intrusive and effusive activity under rift zones, where the oceanic crust is very thin or totally lacking.

We know that the magmatic activity increases in the direction of the flanks of the ridges, where the crust thickness gradually increases. We also believe that our idea may coordinate with the supposition about the low scale of the mantle material upwelling under oceanic ridges. This idea is confirmed by the fact that in rift zones only spinel peridotites occur which are formed at depths less than 60 km (Ringwood, Boyd & McGregor 1964; Boyd & McGregor 1964; etc.).

In conclusion we must say, that this is only a preliminary idea, which will be developed in the future.

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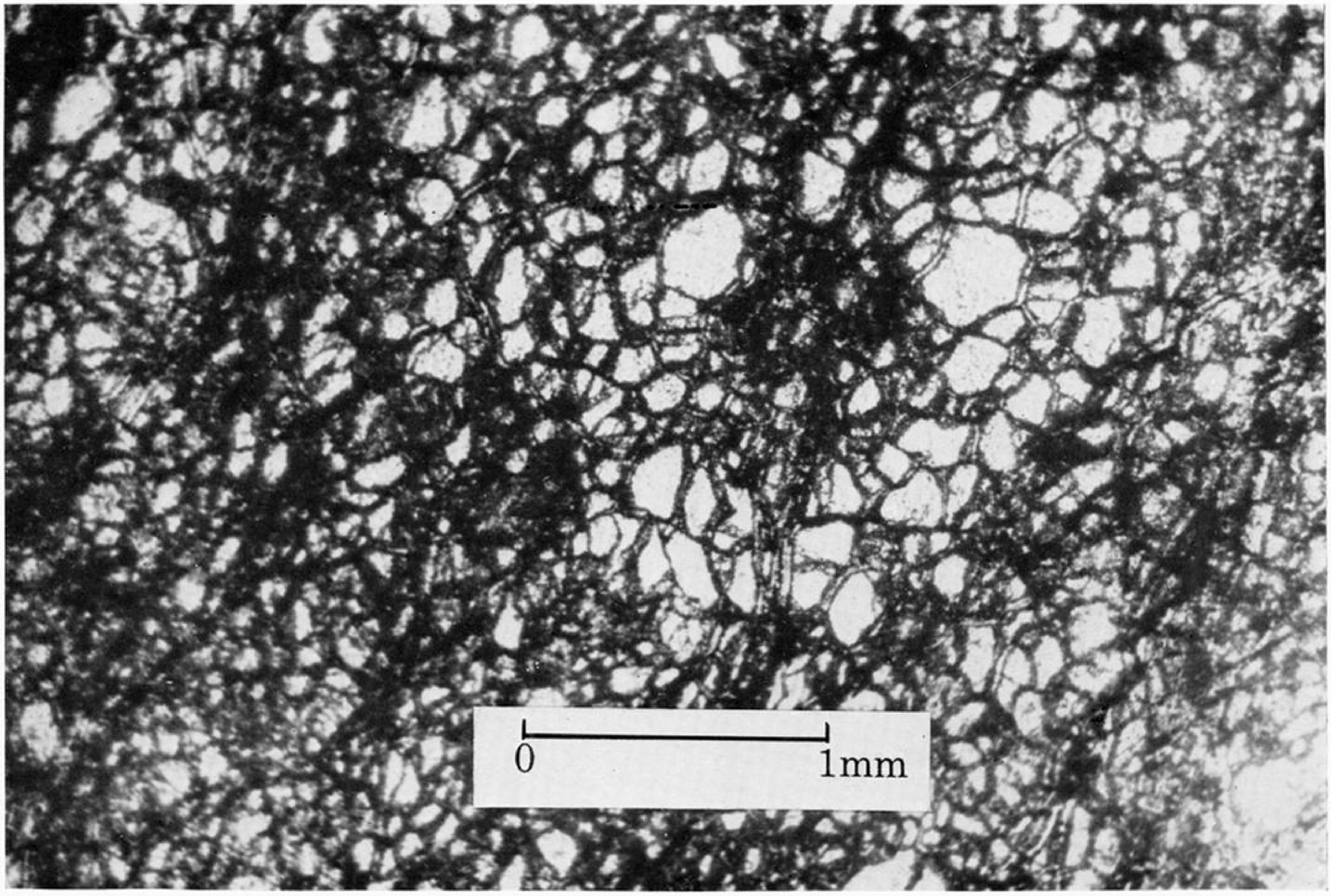

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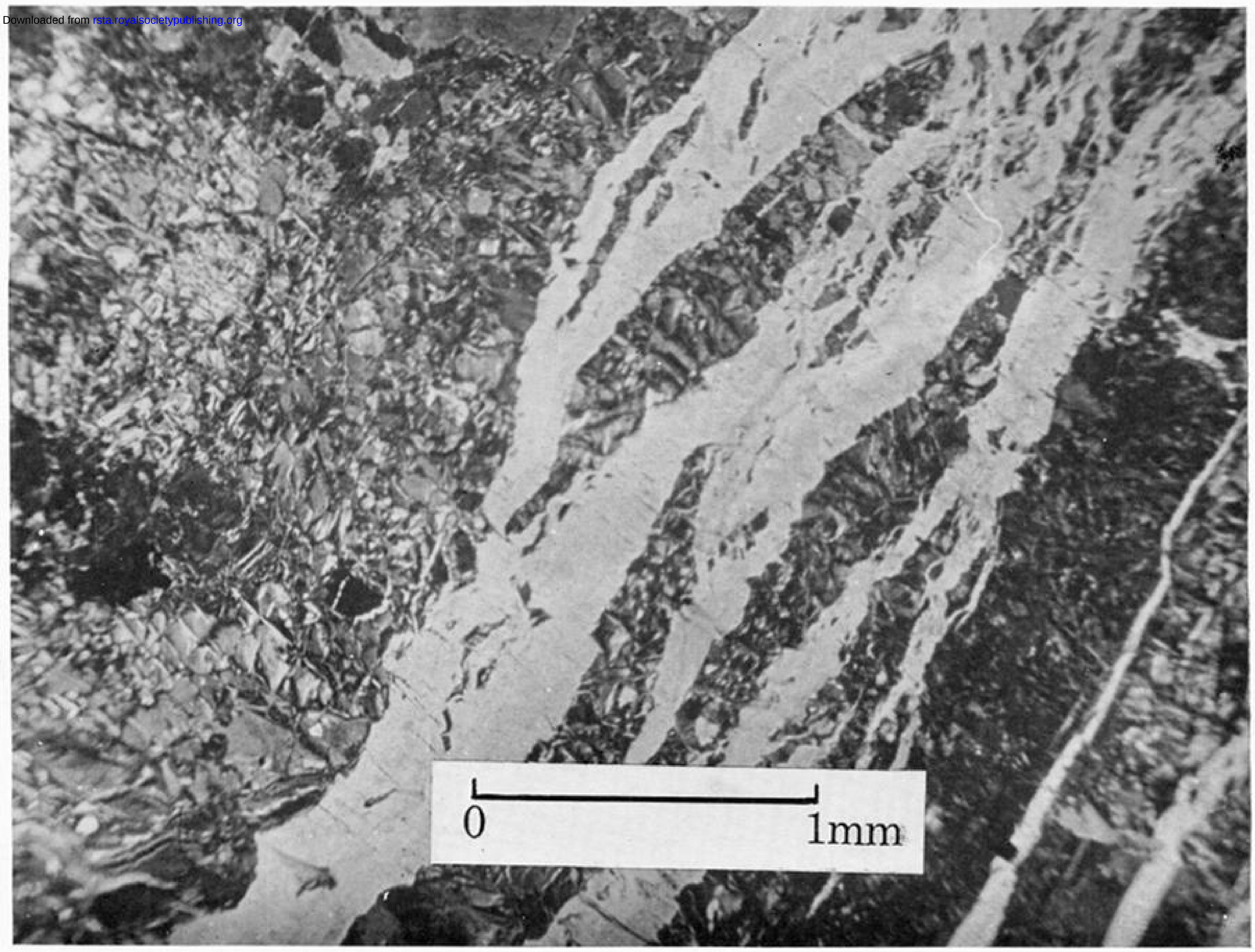

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