SOME HYDROTHERMAL EFFECTS IN A VOLCANIC ROCK FROM A WELL BORING, SANBORN COUNTY, SOUTH DAKOTA [1]

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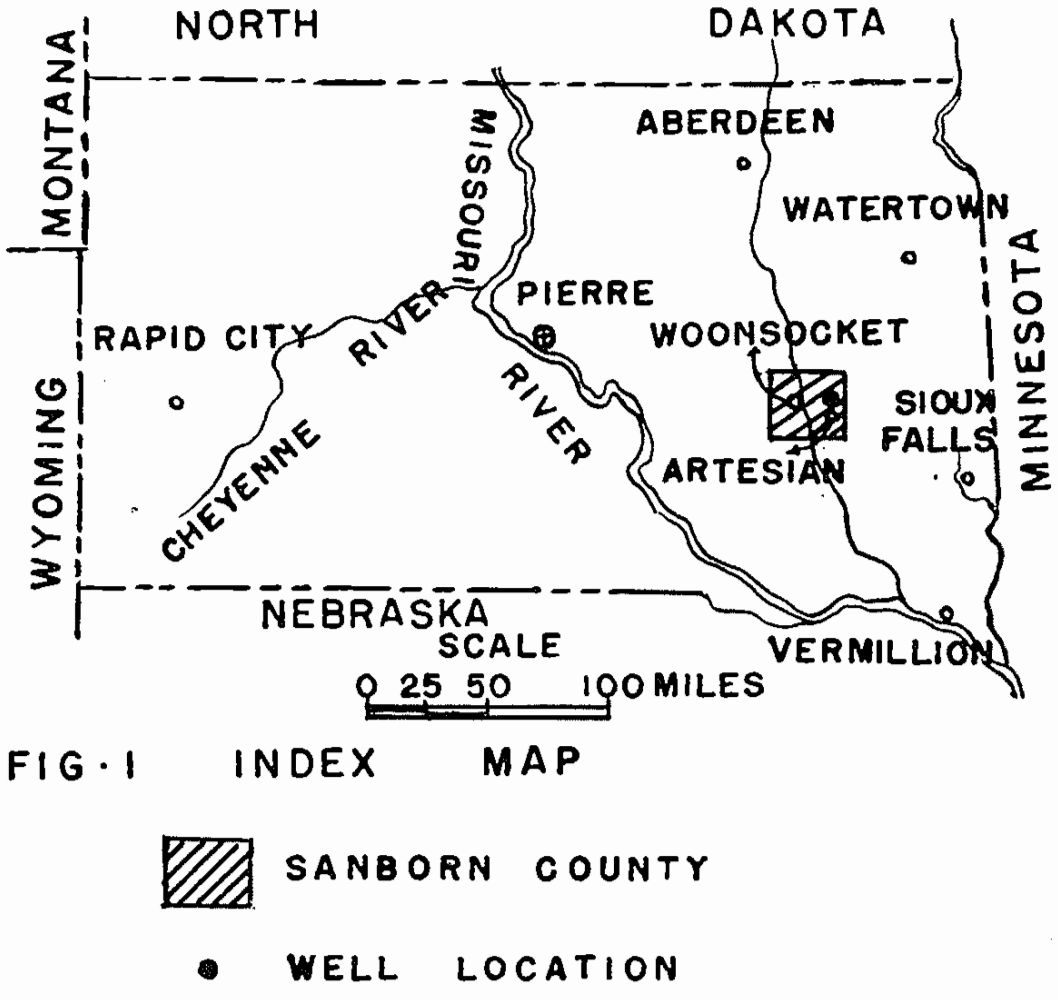
INTRODUCTION

A core of an intensely altered rhyolitic rock was obtained during the drilling of Grassell's farm well, NE ¼ Sec. 21, T. 108 N., R 59 W., in the spring of 1956. The well is about 20 miles northeast of the Sanborn County seat, Woonsocket, and is about nine miles due north of the city of Artesian (Fig. 1). The total depth of the well is 730 feet, and the altered rock was penetrated at a depth of 675 feet. The rock, which is late pre-Cambrian in age, is directly overlain by the Cretaceous Dakota sandstone.



FIG·1 INDEX MAP

Figure 1. Index Map

[1]Publication authorized by the State Geologist.

A laboratory investigation was undertaken to identify the principal mineralogical composition, texture and structure of the altered rock in order to deduce the original rock type as well as the general sequence of alteration.

MINERALOGY

The mineral assemblage is subdivided into two types: 1) Primary minerals, and 2) Secondary alteration products. The primary minerals consist chiefly of quartz and feldspar in association with some sporadically distributed zircon, iron-oxides, and biotite; on the other hand, the minerals derived from hydrothermal alteration mainly are sericite, secondary quartz, and chlorite.

Primary Minerals

Quartz—Primary quartz is one of the chief constituents, and appears mostly as euhedral crystals; some are corroded, and with inlets of the groundmass. Minute inclusions are apatite and iron-oxides. **Feldspar**—The feldspar is recognized by its prismatic crystal form; it is entirely replaced by sericite. On the basis of sericitization this mineral is probably alkali in composition. Near the base of the core, the type of feldspar could not be recognized due to subsequently intense alteration, and because its crystal outlines are merged with the flakes of sericite and quartz aggregates. **Zircon**—The zircon is in prismatic and pyramidal forms, and is commonly associated with streaks of iron oxide minerals; it is sporadically present in the groundmass. **Biotite**—Biotite is very scarce, and with distinct basal section and predominant pleochroism. **Iron-oxides**—The iron-oxides consist chiefly of hematite, and some leucoxene, and occur as streaks and aggregates within the groundmass.

Secondary Alteration Products

Sericite—Sericite, one of the chief alteration products, occurs as scales, fibers or shreds; it is colorless, and wedge-shaped aggregates in the groundmass. It differs from muscovite by a smaller optic angle. **Secondary Quartz**—This quartz appears mainly in the groundmass, and is mosaic, and microcrystalline; wavy extinction is locally present. **Chlorite**—Chlorite appears as scales and fibers, and shows faint pleochroism (Z = colorless, X and Y = pale green). This mineral is commonly associated with some streaks of iron-oxides, and sericite.

PETROGRAPHY

Megascopically this rock is light gray to greenish gray, and porphyritic. The visible phenocrysts consist of rounded to angular quartz with diameters ranging from 0.08 mm to 3 mm. The quartz is enclosed in an aphanitic, gray to greenish gray groundmass, in which some minute scattered cavities, and hematitic and chloritic streaks are sporadically present.

Microscopic study shows that the phenocrysts comprise primary quartz and alkali feldspar. Most of the quartz grains were partly penetrated by subsequent flakes of sericite (Fig. 2). The average grain size of the quartz is about 0.045 mm. The alkali feldspar shows an average grain size about

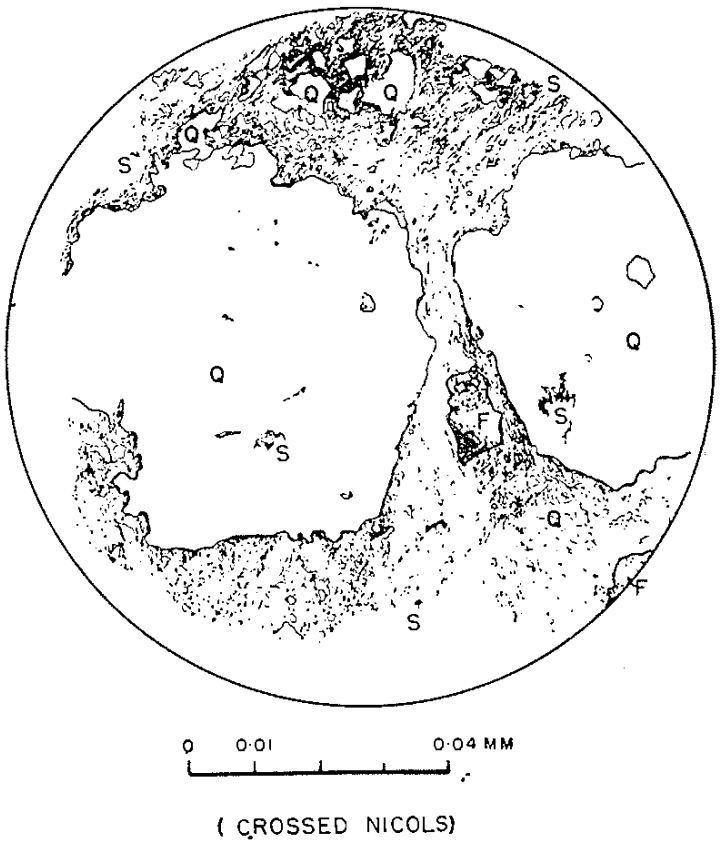


Figure 2. Altered Rhyolitic Rock, Sanborn Co., S. Dak. Phenocrysts Are of Quartz (Q-Partly Penetrated by Sericite-S) and Alkali Feldspar (F-Entirely Replaced by Sericite). Groundmass Consisting of a Crystalline Aggregate of Quartz (Secondary Quartz) and Sericite Flakes

0.04 mm. Subsequently these sericitized feldspar crystals were impregnated by secondary quartz (Fig. 3). The groundmass consists chiefly of microcrystalline and cryptocrystalline aggregates of primary and secondary quartz and sericite flakes. The alternating laminae and streaks of quartz and sericite give evidence of fluxion structure. Iron-oxides streaks are locally present. The relative proportion of phenocrysts to the groundmass is about 2 : 3.

DISCUSSION OF ALTERATION

On the basis of microscopic study this rock is classed as a porphyritic rhyolite, which was subsequently altered chiefly through the process of metasomatism (3*, 6) by hydrothermal solutions. One of the main problems of alteration concerns the introduction of materials from external sources.

*Goldschmidt (1922) defined as "A process of alteration which involves enrichment of the rock by new substances brought in from the outside. Such enrichment takes place by definite chemical reactions between the original minerals and the enriching substances."

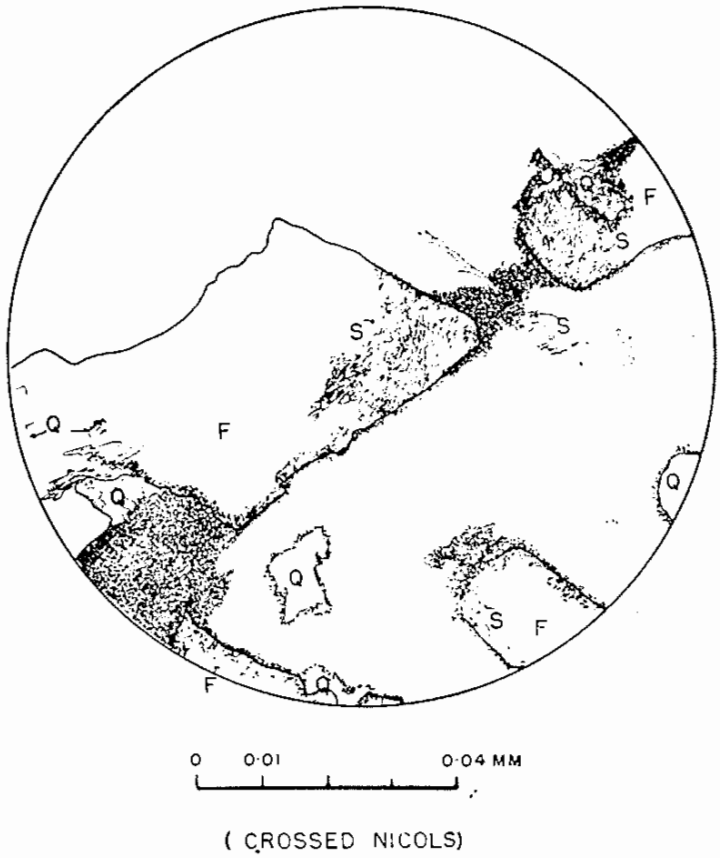


Figure 3. Showing the Replacement of Alkali Feldspar (F) by Sericite (S), Then Impregnated by Secondary Quartz (Q)

If material was added, it is necessary to determine (1) the sequence, (2) the kind, and (3) the source of the added substances.

Sequence of Alteration and Kind of the Added Substances: Microscopic study shows that sericite flakes entirely replaced the feldspar crystals, and partly penetrated the primary quartz; the flakes of sericite are sharply defined against the groundmass. Therefore the earliest stage of this alteration was dominated by the crystallization of sericite without much change in volume of the altered minerals. The alteration of the feldspar crystals to sericite involved the loss of silica, and the simultaneous addition of Al_2O_3 and K_2O. Nevertheless during the time of sericitization, all the potash, including some potash that might come from biotite present in the groundmass, with three times as much alumina, six times as much silica, and twice as much water was incorporated in sericite. Later silicification was performed by the impregnation of silica-bearing solutions into sericitized feldspar (Fig. 3) and the groundmass; the excess silica was thus apparently introduced by hydrothermal solutions. Chlorite is commonly associated with sericite and some iron-oxides; this evidence indicates that chloritization took place after sericitization, and probably simultaneously with silicification. The chloritization is, however, predominant only in the lower part of the core; in other words, this alteration could not reach to the upper part of the core, probably

because of the factor of temperature. The iron and magnesia present in the groundmass, and the remaining alumina were incorporated in chlorite. The remaining silica solution likely was used up in the latest stage of the alteration, and is all assigned to the secondary quartz.

Regarding the nature of hydrothermal solutions and the temperature range of alteration, Gruner (4) mentioned that the presence of slightly basic to acid solutions is necessary for sericitization; furthermore he pointed out that feldspars are altered to sericite at 350° - 525° C.; this alteration occurs in 0.35 N HCl solution. In addition, as a result of Buerger's work (2), if the temperature is high enough to cause crystal growth, it is also high enough to support enough diffusion, which generally causes a wave of replacement. Therefore the writer believes that a rather acid hydrothermal solution with a fairly high level of diffusion played the important role in this alteration.

Source of the Added Substances: The potash, alumina and silica introduced during the processes of alteration were apparently derived from some younger granitic intrusions in adjacent areas. According to drill records in eastern South Dakota, numerous pre-Cambrian granitic intrustions are known (1, 5). Although their definite ages are unknown, nevertheless they may have acted as the main sources of hydrothermal solutions that effected this older rhyolite.

CONCLUSION

The porphyritic rhyolite had been intensely altered through the processes of sericitization-silicification and chloritization-silicification. The added potash, alumina, and some silica were introduced mainly through hydrothermal solutions, which were furnished by adjacent younger pre-Cambrian granitic intrustions.

Sericite and chlorite are the chief alteration products. The sericite is not present in the zone of weathering near the upper part of the core.

SUMMARY

A rhyolitic rock of pre-Cambrian age in eastern South Dakota was intensely altered by hydrothermal solutions, through which potash, alumina and silica were introduced. A sequence of alteration is tentatively deduced as: sericitization-silicification followed by chloritization-silicification. Phenocrysts comprise quartz and alkaline feldspar; the former was partly penetrated by sericite, whereas the latter was entirely replaced by sericite, and subsequently was impregnated by silica solution. Chlorite is sporadically present in the groundmass, chiefly in association with sericite scales, quartz, and iron-oxides. Fluxion structure is recognizable. This alteration might have been produced by the intrusion of later pre-Cambrian granites in adjacent areas.

ACKNOWLEDGEMENTS

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