Pumpellyite-Bearing Rocks in Central Sweden and Extent of Host Rock Alteration as a Control of Pumpellyite Composition

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Abstract. Metamorphic assemblages and mineral compositions in basic to intermediate volcanic rocks of two Precambrian units (the sub-Jotnian and Jotnian) in the Dala region, central Sweden, reveal a history comprising two metamorphic episodes. The sub-Jotnian rocks were metamorphosed during a first episode: the metamorphic grade ranges from prehnite-pumpellyite facies (in a displaced block with sub-Jotnian (?) lava occurring in the border zone of a major impact structure), to pumpellyite-actinolite facies, and to greenschist facies in the lower part of the unit. The unconformably overlying Jotnian rocks were metamorphosed to prehnite-pumpellyite facies during a subsequent episode, which also left its imprint in the sub-Jotnian basement. Two other Jotnian sequences in central Sweden are in the same facies.

There are systematic chemical differences in some of the secondary minerals. Sphenes contain more Al, and epidotes and pumpellyites are more Fe-rich in Jotnian (prehnite-pumpellyite facies) rocks compared with sub-Jotnian rocks of pumpellyite-actinolite facies. Most epidotes in Jotnian lavas are remarkably rich in Fe, with a replacement of Al by Fe$^{3+}$ up to 1.5 atoms per formula unit (Psso). Compositions of epidote and pumpellyite in pervasively altered rocks vary sympathetically.

Pumpellyite composition is partly controlled by the extent of alteration in its host rock. There is a trend for the compositional field of pumpellyite to shrink and shift away from the Al corner of the Al – Fe* – Mg triangle with increasing extent of host rock alteration. This trend is most evident in Jotnian rocks. Since the fields in the Al – Fe* – Mg triangle given in the literature as representative of pumpellyite from Sweden referred to lenses in biotite in “otherwise quite ordinary quartzofeldspathic gneisses and granitoid rocks” (Zeck 1971; see also Elbers 1971) from the Precambrian of southern Sweden. A model for the post-Svecokarelian geologic evolution of central Sweden taking burial metamorphism into account is given by Nyström (1982).

The purpose of this paper is: (a) to describe the pumpellyite-bearing assemblages in post-Svecokarelian rocks of central Sweden, (b) to show that these assemblages were formed during more than one episode of low-grade metamorphism, and (c) to discuss the influence of extent of host rock alteration on the composition of pumpellyte.

Geologic Background

The largest area of sub-Jotnian rocks in central Sweden is located in the Dala region (Fig. 1). A description of the geology of this region is given by Hjelmqvist (1966; see also Lundqvist 1968). The sub-Jotnian Upper Dala formation rests unconformably on the Svecokarelian basement. The thickness of the formation is assumed to be several kilometres (Lundqvist 1968, p 79). It is dominated by acid ignimbrites, although volcaniclastic rocks and basic to intermediate lavas-including an extensive sheet of andesitic ignimbrite- are locally abundant. The traditional name for the basic to intermediate volcanics, *Dala porphyrites*, is used in this paper. The Upper Dala formation is intruded by high-level granitoids and subvolcanic porphyries. The age of the formation is not yet settled. A Rb-Sr dating of acid volcanics has yielded 1635 Ma (Welin and Lundqvist 1970; Welin 1979).

The most common type of Dala porphyrite is of andesitic to latitic composition with phenocrysts of intermediate plagioclase, clinopyroxene and magnetite as primary minerals. Many flows carry in addition phenocrysts of biotite and K-feldspar. Basaltic flows with calcic plagioclase, clino-
pyroxene and magnetite also occur. Their porphyritic texture is less pronounced.

Jotnian basic lavas are known from three areas in central Sweden (Fig. 1). They occur as intercalations in up to 1 km thick sequences of red continental sandstone deposited in fault-margin basins and grabens. The upper part of many flows is highly amygdaloidal. The lavas are of rather Fe-rich basaltic composition with calcic plagioclase, clinopyroxene and titanomagnetite as primary minerals (Gorbatschev 1967; I. Carlsson, unpubl. data). They are referred to as the Jotnian sandstone and basalt, Granholmen and Falun GAV_ H in this paper, even if they are in a strict sense, metabasalts. The Jotnian has often been compared with the Keweenawan of North America (see Geijer 1963, p 133).

The Jotnian sequence in the Dala region (Hjelmqvist 1966) lies unconformably on sub-Jotnian rocks; the other two occurrences (Gorbatschev 1962, 1967) overlie the Svecofennian basement. It is not known if the Jotnian sequences in central Sweden are coeval. Their depositional environment argues against the idea that they once formed a continuous cover. It is more probable that subsidence/deposition (and burial metamorphism) took place at different times in different areas. The minimum age of the Jotnian sequence in the Dala region is ca. 1220 Ma (Rb-Sr age of crosscutting dolerites; Patchett 1978).

Metamorphic Assemblages

The sub-Jotnian Dala porphyrites and Jotnian basalts exhibit preserved volcanic structures and textures. The primary minerals are, however, partly or totally replaced by secondary phases. The extent of alteration can be correlated with several factors: metamorphic grade, rock composition, grain size, precursor mineral and permeability (initial or due to subsequent fracturing), among others. Thus, Jotnian basalts are in general less altered than sub-Jotnian lavas of corresponding SiO₂ content but of higher metamorphic grade. Many Dala porphyrites have relicts of primary minerals, in contrast to the more extensively altered acid volcanics of the same grade. As a rule, the groundmass of the Dala porphyrites is reconstituted whereas the phenocrysts often persist as relicts. Phenocrysts of plagioclase were more susceptible to alteration than those of pyroxene. Few or no volcanic relicts are present in pyroclastic intercalations, brecciated flow tops and parts of flows rich in amygdalae and veinlets.

The altered sub-Jotnian and Jotnian volcanics are spilitic in a mineralogical – though not chemical – sense. Comparisons of samples with different extent of alteration, from the same or similar flows, indicate that the alteration did not cause large changes in Si, Al and total Fe contents (Nyström, unpubl. data; I. Carlsson, unpubl. data). More mobile elements such as Na, Ca and K have not changed as much as in some other burial metamorphosed continental lavas, for example, the Keweenawan flows (Jolly and Smith 1972). The Fe₂O₃/FeO ratio is usually 2–4 times higher in strongly altered parts of Jotnian basalts compared with relatively unaltered parts. This ratio varies much less in the Dala porphyrites because they are largely altered, with relict phases persisting only in phenocrysts.