

# LIQUID IMMISCIBILITY IN SUEVITE MELT, GARDNOS IMPACT CRATER.

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**Introduction:** Studies of melt fragments in suevite from the Gardnos impact crater, Norway, show liquid immiscibility between two silicate phases. The Gardnos impact crater is located in southern Norway. The target rocks consist mainly of granitic gneiss with minor amphibolite and quartzite. An unusual feature of the Gardnos impactites is that they are 5-10 times enriched in carbon compared to the target rocks [1]. The carbon is probably derived from a carbon-rich target rock, the Alum shale, no longer present at the impact site [1, 2]. The age of impact is not well constrained, between 900 Ma (deformed pegmatites) and 400 Ma (Caledonian Orogeny) [1], but since the Cambrian Alum shale is the most likely source of carbon, the age of impact was probably between 550 Ma (Cambrian) and 400 Ma. The Gardnos impactites include lithic breccias and melt breccias (melt-matrix breccia and suevite).

**Melt petrography:** The Gardnos suevite (Fig. 1) consist of melt fragments normally with a size of 1-20 mm, together with rock and mineral fragments up to a few cm in size, in a fine grey-green lithic matrix of mainly granitic material (feldspar and quartz). The melt fragments are very often irregular and have thin stringers of melt extending from the fragments into the matrix, which is indicative of flow after deposition (Fig. 2). Although the Gardnos impactites were metamorphosed during the Caledonian Orogeny (400 Ma), shock indicators such as pdf in quartz and feldspar and other impact signatures are still preserved [2]. However, the mineralogy has in many cases changed. The formerly glassy melt fragments in the suevite are devitrified and their present mineralogy, stilpnomelane and chlorite, is secondary but it probably reflects the composition of the precursor melt phases. Both of the two silicate phases (stilpnomelane and chlorite) are present in most melt fragment and show immiscibility textures such as:

- (i) Intermingling tunnels of one phase within the other (Fig. 2). Similar features are also seen in silicate-carbonate immiscibility [3].
- (ii) Sharp boundaries with curved menisci between the two phases (Fig. 3).
- (iii) Budding between phases (Fig. 4). Budding structures are described as immiscibility textures by MacDonald et al. [4].
- (iv) Flow textures with flow of one phase within the other, as in described by Graup [5].

No unaltered glass has survived in the Gardnos suevites.



Fig. 1. Gardnos suevite with dark irregular melt fragments in a lithic matrix.

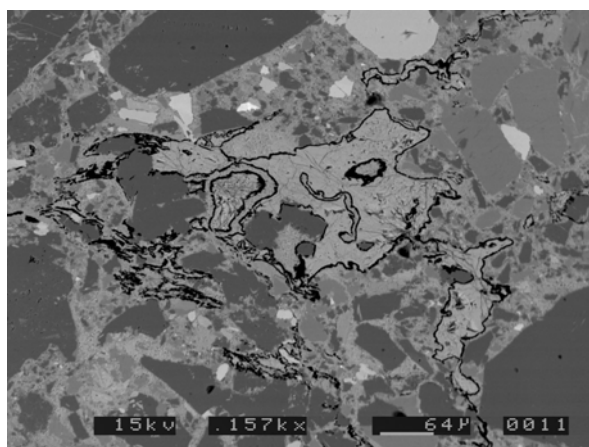


Fig. 2. Scanning electron micrograph of an irregular melt fragment, Gardnos suevite, with stringers of melt that are evident of flow after deposition.

All the carbon in the suevite occurs in the melt fragments, which suggests that the carbon was included in the melt when the carbon-rich target rock was melted. The carbon gives the melt fragments a dark colour and appears as a layer up to 20 microns thick on the boundary between the two phases and on the boundary between the stilpnomelane phase and the matrix but not between the chlorite phase and the matrix. This suggests that the carbon precipitated from the stilpnomelane phase. Sub-micron blebs of carbon also occur within the stilpnomelane phase and to a lesser degree in the chlorite phase. This distribution could be explained, in a direct analogy with the cooling behaviour of carbon-rich steel [6], by the precipitation of excess carbon beyond the eutectoid composition for the precursor melt of the

stilpnomelane phase, followed by a eutectic mixture of carbon and glass/silicate phases. The stilpnomelane phase is enriched in  $\text{SiO}_2$  (~48 wt%) and  $\text{K}_2\text{O}$  (~2 wt%) compared to the chlorite phase (~27%  $\text{SiO}_2$  and <0.2wt%  $\text{K}_2\text{O}$ ). Carbon precipitation from the potassium-enriched phase is consistent with evidence from diamond chemistry indicative of carbon derivation from the alkali-rich component of immiscible mantle-derived liquids [7]. Inclusions of titanite crystals are common in the chlorite phase (Fig. 5) and indicate that the precursor melt phase was enriched in Ti. Liquid immiscibility between titanium-rich silica melt and titanium-poor silica melt is also observed in the Bedout impactites [8], as well as in the Ries suevites where the relatively silica and potassium poor phase is enriched in titanium [9].

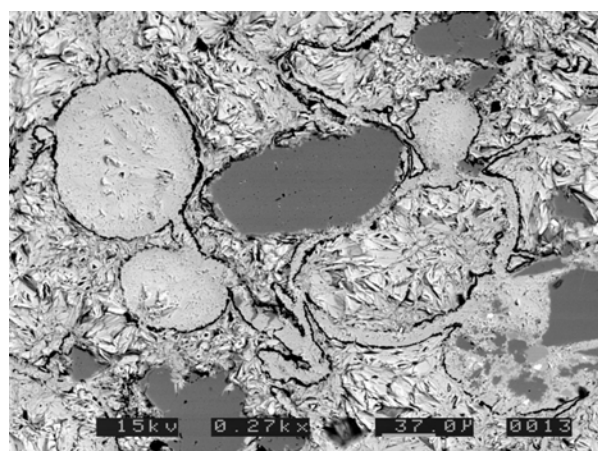


Fig. 3. Scanning electron micrograph of intermingling tunnels and curved menisci between the two immiscible phases in the Gardnos suevite melt. Circular pattern is due to a low-angle intersection of section with tubular structure.

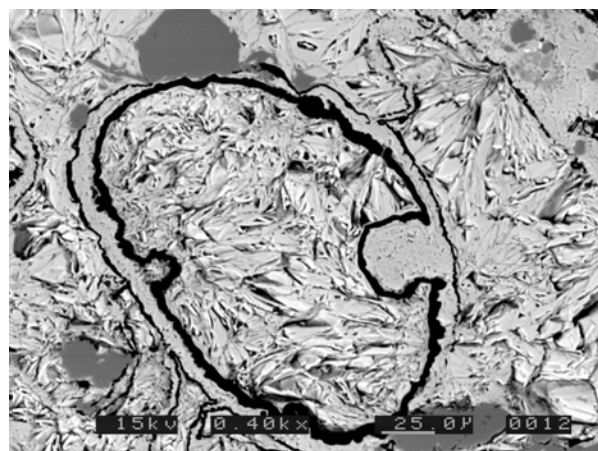


Fig. 4. Scanning electron micrograph of budding between the two immiscible melt phases, Gardnos.

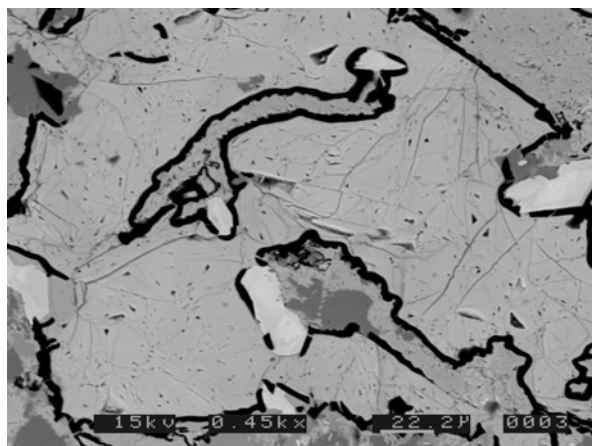


Fig. 5. Scanning electron micrograph of intermingling tunnels of the chlorite phase within the stilpnomelane phase. The chlorite phase has inclusions of titanite crystals (bright colour).

**Liquid immiscibility in impact melts:** Although silicate-silicate liquid immiscibility is less common than silicate-carbonate immiscibility it is widespread in glasses [10, 11]. In an impact environment the melts experience a rapid drop from very high pressure and temperature [12], bringing them into a P-T field of liquid immiscibility. The melt from Gardnos suevite show textural evidence of silicate-silicate immiscibility and examples of silicate-silicate immiscibility from other impact melts include Ries [5], Bedout [8] and West Clearwater lake [13]. Examples of silicate-carbonate immiscibility from impact melts include: Ries [5], Haughton [14] and Chicxulub [15].

**References:** [1] French B. M. et al. (1997) *Geochimica et Cosmochimica Acta*, 61, 873-904. [2] Gilmour I. (2003) *Geochimica et Cosmochimica Acta*, 67, 3889-3903. [3] Brooker R. A. (1998) *Journal of Petrology*, 39, 1905-1915. [4] MacDonald R. (1993) *Contributions to Mineralogy and Petrology*, 114, 276-287. [5] Graup G. (1999) *Meteoritics and Planetary Science*, 34, 425-438. [6] Higgins R. A. *Engineering metallurgy Part 1. Applied Physical Metallurgy* (Edward Arnold, London, 1993) [7] Korsakov A. V. (2004) *Terra Nova* 16, 146-151. [8] Becker L. et al. (2004) *Science*, 304 (5676), 1469-1476. [9] Osinski G. R. (2004) *Meteoritics and Planetary Science*, 39 (10), 1655-1683. [10] Philpotts A. R. (1979) *Journal of Petrology*, 20, (99-118) [11] Philpotts A. R. (1982) *Contributions to Mineralogy and Petrology*, 80, 201-218 [12] Koeberl C. *Mineralogical Magazine*, 66, 745-768 [13] Dence M. R. (1974) *Contributions to Mineralogy and Petrology*, 46, 81-97. [14] Osinski G. R. (2001) *Earth and Planetary Science Letters*, 194, 17-29. [15] Schulte P. (2003) *International Journal of Earth Science*, 92, (114-142).