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Euhedral crystals in interstitial pores of the Baszkówka and Mt. Tazerzait L5 chondrites

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Euhedral to anhedral crystals of the main meteoritic minerals are found in interstitial pores of the unshocked L5 chondrites Baszkówka and Mt. Tazerzait. The composition of these pore minerals is the same as elsewhere in the meteorite. They must have grown from a vapour phase during metamorphic equilibration of the meteorite minerals. The pores are primary features, i.e. open space remaining after compaction of the constituents of the meteorite.

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INTRODUCTION

The meteorite Baszkówka fell on August 25, 1994, and was soon recovered and brought to the Polish Geological Institute in Warszawa (Stepniewski *et al*., 1996). During the examination of the meteorite, primary holes were detected on cut surfaces. At higher magnification, it was seen that these pores contain small shiny crystals. Similar pores with crystals were found at about the same time in the meteorite Mt. Tazerzait, which fell on August 21, 1991 (Grossman, 1997). Both meteorites are L5 chondrites. The similarity in month of fall and the unusual pore crystals suggested a possible relation between these two chondrites and prompted a closer inspection. Rare gases and the exposure ages were determined on both meteorites (Scherer and Schultz, 2001). A preliminary description was given by Wlotzka *et al.* (1997). This paper describes the minerals found in the pores and discusses their formation.

OBSERVATIONS

The Fa-content in olivine and the Fs-content in orthopyroxene of both chondrites are within the limits of error identical: Fa 24.2, Fs 20.8 for Baszkówka (Wlotzka, 1995), Fa 24.6, Fs 20.8 for Mt. Tazerzait (Grossman, 1997). Also the petrographic textures are very similar, both are L5 chondrites. The mm-sized pores are visible already on the cut surfaces of the meteorites. In Baszkówka the pores are clearly interstitial to chondrules and other coarse constituents, their outline is irregular (Pl. I, Fig. 1). In Mt. Tazerzait the pores appear more rounded, the whole texture is more compact (see Pl. I, Fig. 3; Pl. III, Fig. 4).

In thin section the pores of both meteorites look unsuspicious, i.e. they do not stand out as special features. Plate I, Figure 2 shows a thin section of Baszkówka in reflected light at low magnification, the interstitial nature of the pore space is evident. Pores in Mt. Tazerzait are shown in transmitted light in Plate I, Figure 3. At higher magnification, the minerals adjacent to the pore show linear or slightly curved surfaces (Pl. I, Fig. 4), sometimes small crystals are found protruding into a pore (Pl. I, Fig. 5). Microprobe measurements show that the composition of the silicate minerals in these pores and away from the pores is the same in Mt. Tazerzait (Table 1), similar results were obtained for Baszkówka. This does not exclude, however, that small grains, only seen in the SEM, may have somewhat deviating compositions.

With the Scanning Electron Microscope the euhedral nature of these pore crystals is seen. A qualitative X-ray analysis shows that all main constituents of the meteorite are present: ol-

Table 1

Electron microprobe measurements of silicate minerals in Mt. Tazerzait

Minerals	Olivine		Orthopyroxene		Plagioclase	
	A (4)	B (10)	A (3)	B (5)	A (3)	B (9)
SiO_2	38.53	38.65	55.95	56.02	66.82	67.11
Al_2O_3	–	–	0.16	0.14	22.05	21.94
MgO	38.85	39.28	29.51	29.55	–	–
CaO	–	–	0.90	0.72	2.22	2.32
Na_2O	–	–	–	–	9.65	9.41
K_2O	–	–	–	–	1.05	1.03
MnO	0.53	0.52	0.53	0.54	–	–
FeO	23.75	23.30	14.19	14.29	0.48	0.42
Total	101.66	101.75	101.24	101.26	102.27	102.23

A — in the bulk meteorite, B — in pores; number of analyses in brackets; analyst J. Otto

ivine, pyroxene, metal, troilite, plagioclase, also chromite. The following SEM pictures show examples.

Olivine predominates in the pores. The crystals are usually stubby and show crystal faces (Pl. I, Fig. 6), often they are intergrown in blocky aggregates (Pl. II, Fig. 1) . Also elongated crystals as shown in Plate II, Figure 2 are found. Plate II, Figure 3 shows a large olivine with a hole on one face. Such holes and indentations are common (Pl. II, Fig. 4), especially in Baszkówka. Often small crystals of other phases are found in such indentations, usually feldspar grains (see Pl. III, Fig. 1). Growth steps are visible at higher magnification (see Pl. II, Figs. 2 and 4).

Pyroxene is less abundant, the crystals are usually stubby like the olivines. More unusual grains are shown in Plate II, Figure 5, a multigrain aggregate in Plate II, Figure 6. Feldspar shows a peculiar behaviour: it occurs in small, rounded grains on the surface of other silicate crystals (Pl. III, Fig. 1, see also Pl. II, Fig. 4), or as larger assemblages of such grains (Pl. III, Fig. 2). In Mt. Tazerzait better crystallised tabular feldspar crystals were found (Pl. III, Fig. 3). Also metal (Pl. II, Fig. 7; Pl. III, Fig. 4) and troilite (Pl. III, Fig. 5) occur in rather large, euhedral crystals. Plate III, Figure 6 shows a small chromite crystal in a pore of Mt. Tazerzait.

DISCUSSION

Empty spaces between chondrules or mineral grains are common in chondrite thin sections, mainly due to plucking of metal grains or chondrules during thin section preparation. But most unshocked chondrites show a natural porosity of several volume-percent, as shown by Christophe Michel-Levy (1978) by special impregnation techniques. More recent pore volume measurements by Consolmagno *et al.* (1998) give an average value of 12% porosity for unshocked chondrite falls, but values up to 30% have been measured.

More or less euhedral crystals in chondrite pores or vugs have been described in the literature before. We have to distinguish three different occurrences, they are listed here according to their sequence in time:

1. Free olivine crystals embedded in a fine-grained matrix in carbonaceous chondrites. They show irregular, linear ridges on their crystal faces and were probably formed by condensation in the solar nebula (Olsen and Grossman, 1974).

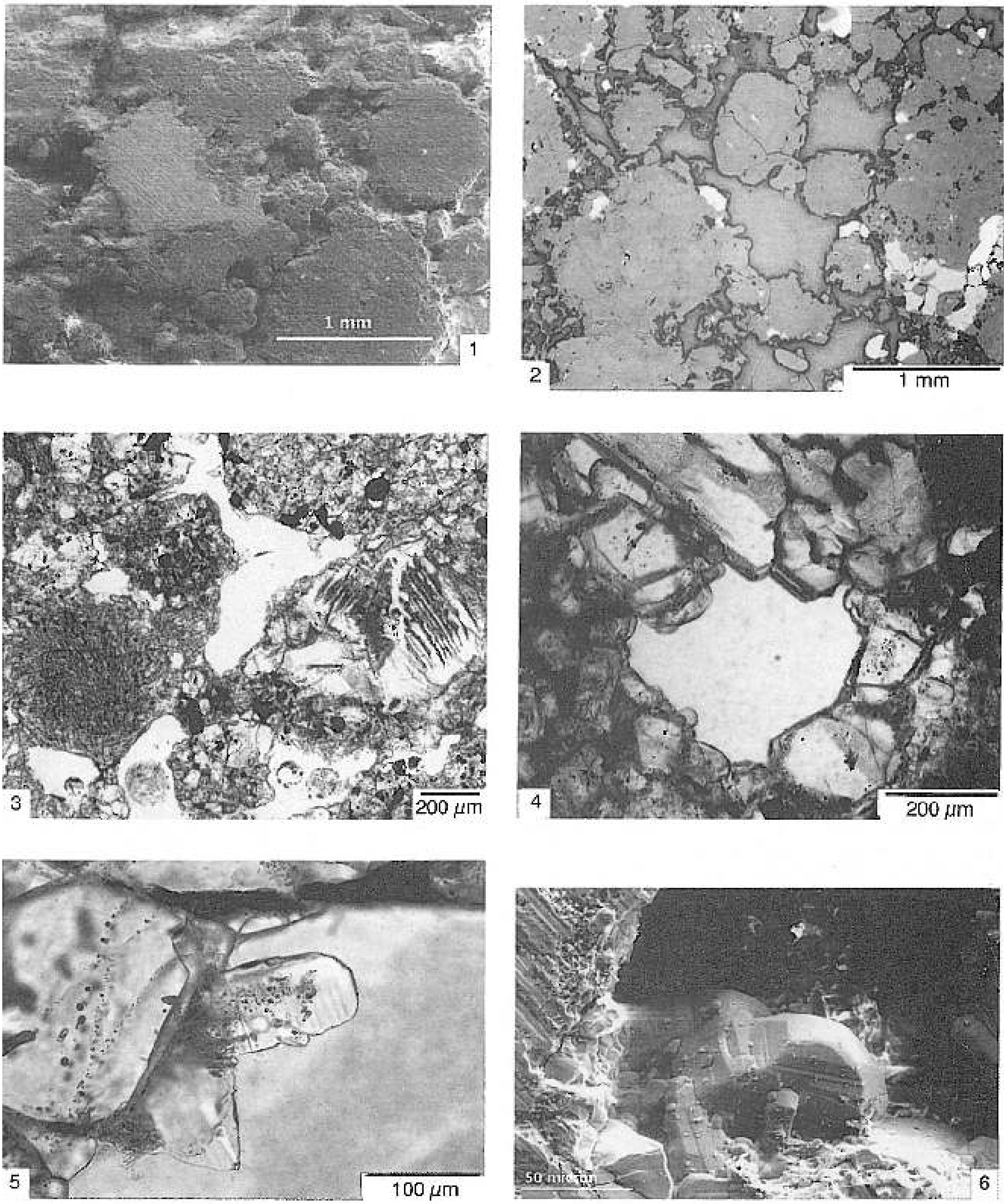
2. Crystals of the main meteorite minerals in interstitial pore space of unshocked, equilibrated chondrites. Such crystals with euhedral shapes were described by Christophe Michel-Levy (1979) in Sena, an unshocked H4-5 chondrite.

3. Crystals lining vugs in shocked chondrites, as described by Fruland (1975) and Olsen (1981) for Tadjera, Farmington, Rose City and others. These vugs were formed by vapour expansion in partly melted chondrites and the crystals are supposed to have grown by condensation during cooling (Olsen, 1981).

Baszkówka and Mt. Tazerzait represent clearly the second case. The pores are interstitial to the main meteorite constituents, as chondrules and mineral grains (Pl. I, Fig. 2). We interpret these interstitial pores as primary, remaining after the loose compaction of the chondrite constituents. They contain rather stubby, euhedral to anhedral crystals of all main meteorite minerals. Only small differences exist between Baszkówka and Mt. Tazerzait. The latter seems more advanced in equilibration, so that the pores became more rounded and the crystals in them do not show the holes and indentations seen in Baszkówka.

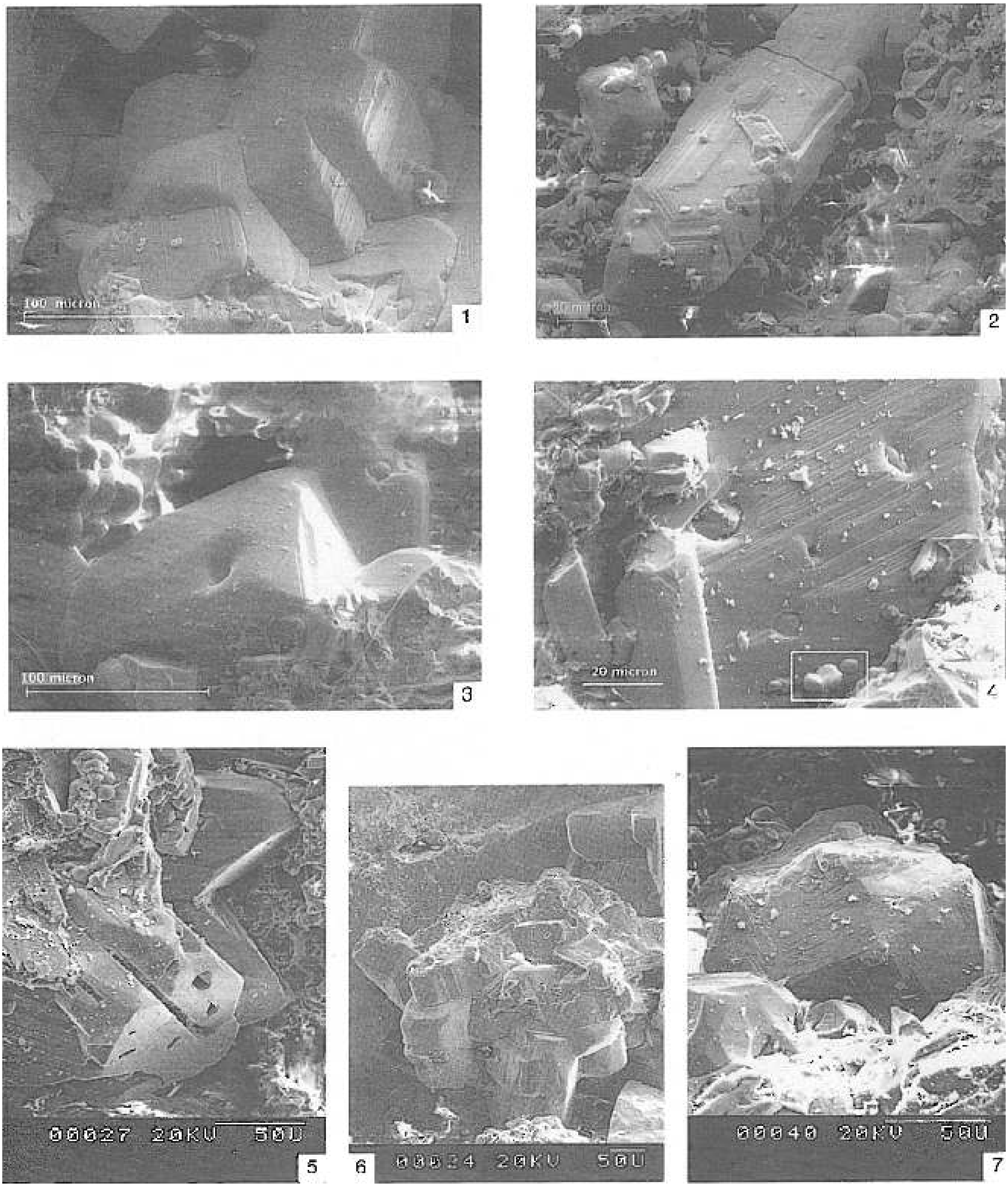
It is noteworthy that no “alien“ minerals were found, especially no zeolites or other water-containing minerals. The crystal faces are smooth down to the nanometer scale, often they show straight or curved growth steps. The composition of the pore minerals is the same as elsewhere in the meteorite, i.e. they are equilibrated. This fact suggests that these crystals developed during metamorphic equilibration of the chondrite from a vapour phase migrating through the loosely compacted rock. The temperature of their growth will lie around 800°C, as determined for the equilibration temperature of type 5 chondrites

PLATE I



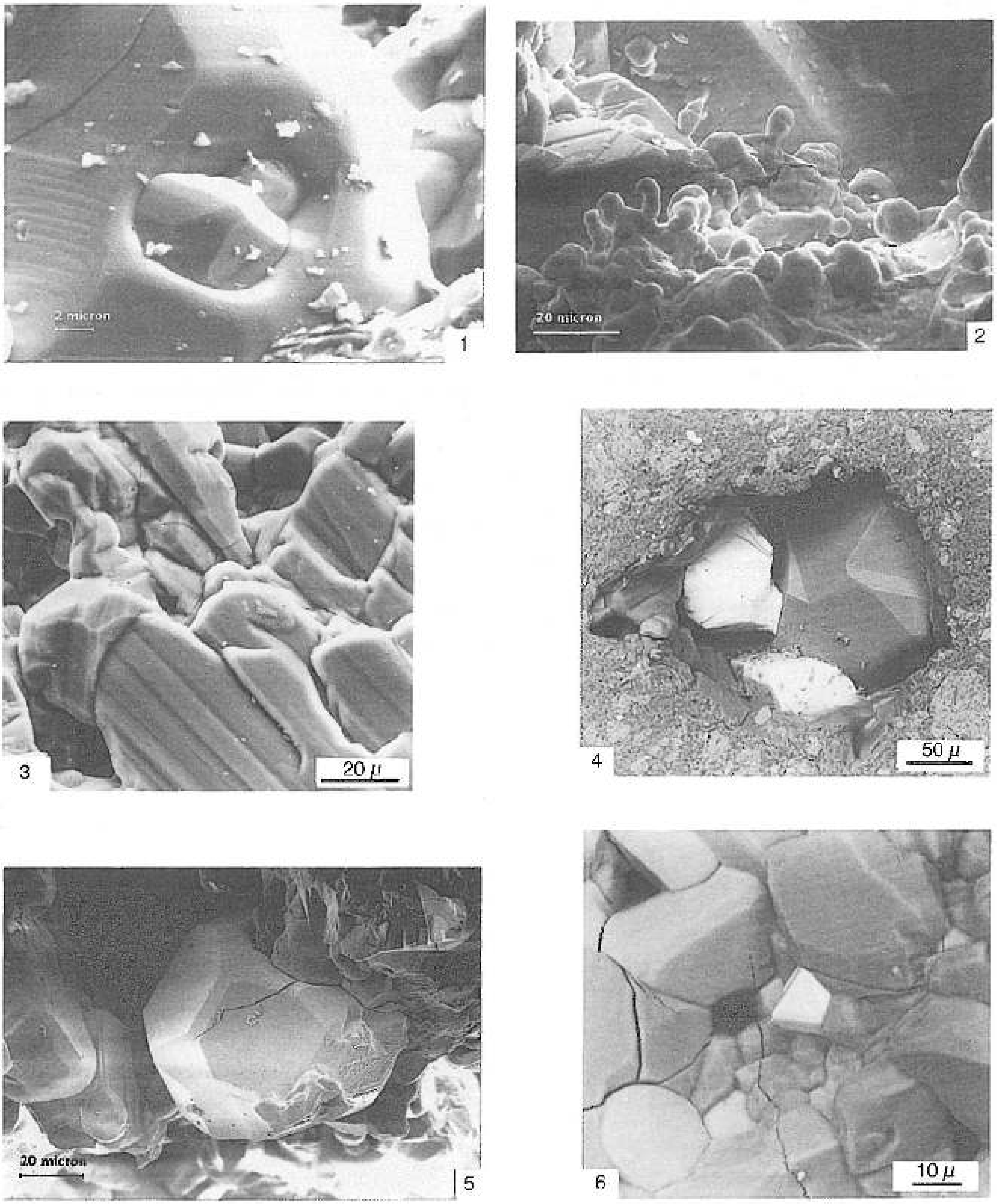
1. SEM picture of a cut surface of Baszkówka at low magnification; pores occur interstitial to chondrules and coarse grains; lighter grey grain in the middle is metal. ***2***. Thin section of Baszkówka in reflected light; the interstitial nature of the abundant pore space is evident. ***3***. Thin section of Mt. Tazerzait in transmitted light; interstitial pores are similar to those in Baszkówka, but less irregular. ***4***. A pore in Baszkówka at higher magnification (thin section, transmitted light); note the mostly straight crystal boundaries towards the open pore space. ***5***. Olivine crystals protruding into a pore in Baszkówka (thin section, transmitted light). ***6***. SEM picture of olivine crystals in a pore in Baszkówka

PLATE II



1. Stubby olivine crystals in Baszkówka (SE picture). ***2***. Elongated olivine in Baszkówka (SE picture). ***3***. Large olivine crystal in Baszkówka with funnel-shaped hole on one face (SE picture). ***4***. Olivine crystal in Baszkówka with growth steps and indentations; the three small crystals in the white frame are feldspars (Baszkówka, SE picture). ***5***. Pyroxene crystals with growth channels in Baszkówka (SE picture).***6***. Blocky aggregate of pyroxene crystals in Baszkówka (SE picture). ***7***. Large nickeliron crystal with growth steps in Baszkówka (SE picture)

PLATE III



1. Small feldspar grain grow in an indentation of an olivine crystal (Baszkówka, SE picture). ***2***. Assemblage of rounded feldspar grains, at left and middle background cactus-like forms with stems growing on olivine grains (Baszkówka, SE picture). ***3***. Tabular feldspar crystals in Mt. Tazerzait (SE picture). ***4***. A rounded pore in Mt. Tazerzait with pyroxene (right), metal (white grain at left) and troilite (white grain, lower side) crystals (BSE picture). ***5***. Crystal of troilite in Mt. Tazerzait (SE picture).***6***. Small crystal of chromite (white) in a pore of Mt. Tazerzait (BSE picture) from the olivine-chromspinel Fe-Mg exchange thermometer (Wlotzka, 1985). Chromite Fe/Mg-ratios are similar in Baszkówka and Mt. Tazerzait to that in other L5 chondrites, indicating similar equilibration temperatures. The equilibrated composition of plagioclase in the pores is remarkable, because it is known that Na and K contents can be changed drastically by vapour phase exchange (Wlotzka *et al.,* 1983).

It is noteworthy that the fine-grained matrix of type 3 and 4 chondrites is absent in Baszkówka and Mt. Tazerzait. Apparently it disappeared during metamorphic equilibration and formation of the pore crystals. On the other hand, most type 3 chondrites (Tieschitz, Sharps, Bremervörde and others) have a rather dense texture with little interstitial pore space, whereas many of the more equilibrated type 4‘s, like Bjurböle and Saratov, have a loose texture full of pores. This applies also to the type 5 Baszkówka and Mt. Tazerzait. A direct transformation of the dense type 3 chondrites into these porous ones seems difficult to accomplish. A possible explanation is that loosely bound type 3 precursors of Baszkówka or Mt. Tazerzait, if they existed, were easily destroyed during impacts on their parent body, necessary to propel them from there into Earth crossing orbits.

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