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Melt inclusions in pyroclastic quartz from the Carboniferous deposits of the Holy Cross Mts, and the problem of magmatic corrosion

ABSTRACT: Pyroclastic quartz from Carboniferous clayey sediments of the Holy Cross Mts bears silicate glass inclusions, frequently altered or refilled by pneumatolytic and hydrothermal solutions. Homogenization and crushing stage studies have yielded the quartz crystallization and probably eruption temperature 790—810° C, cooling rate, and have evaluated changes of pressure of volatiles. The invalidity of common interpretation of the so-called "magmatic corrosion" phenomena is presented

INTRODUCTION

Melt inclusions in minerals are the only but minute portions of true magma submittable to immediate observations. The most extensive studies in this field are carried in the Soviet Union (Sobolev & Kostyuk 1975). Important paper by Roedder (1979) presents mostly American studies of melt inclusions in terrestrial and lunar rocks. This kind of studies is developed also in France (Clocchiatti & Perna 1974, Clocchiatti & Westercamp 1974). In Poland this paper presents the first attempt to study the magmatic inclusions.

The studied sample consisted of 40 euhedral quartz crystals 0.5 to 1.5 mm in size, separated from the pyroclastic rock strongly altered to clayey one. The investigated material has been collected by Dr. E. Olempska (Institute of Paleobiology Polish Academy of Sciences) whilst sampling for ostracodes one layer of green shales from a sequence of lowermost Tournaisian (*Siphonodella* conodont zone) green and cherrish shales exposed at Kowala (trench *II* of Olempska 1979, p. 65; *see also* Olempska 1981) in the northern limb of the Gałęzice syncline (*see also* Szulczewski 1971, Text-fig. 1; and 1978, Text-fig. 1). The presence of pyroclastic material within a condensed sedimentary sequence that straddles the Famennian/

/Tournaisian boundary has long been known in the Holy Cross Mts (Czarnocki 1928, 1933), and the regional development of this sequence in the Gałęzice syncline has recently been studied in details by Szulczewski (1978). All the sedimentary gaps within this sequence, the same as the presence of pyroclastic material are attributed to processes connected with the early Variscan tectonic movements, precisely with the Bretonic phase (Czarnocki 1928, 1933; Szulczewski 1978).

Acknowledgements. Separation of quartz crystals from the rock specimen was performed by Dr. E. Olempska, whose contribution to this study and kind consultations are graciously acknowledged. The author is also very indebted to Professor A. Radwański for his help in completion of geological characteristics of the sample location.

METHODS

Homogenization studies were performed by means of quenching method (Roedder 1972) applying the ability of silicate melts to supercooling with formation of glass maintaining the same phase ratios as at temperature before quenching.

This method permits microscopic observations of homogenization process using high magnifications with immersion and at room temperature. Heating runs were made in microfurnace of the author's construction (Text-fig. 1a) calibrated also by quenching method on melting points of metals and salts (Text-fig. 1b). Cooling

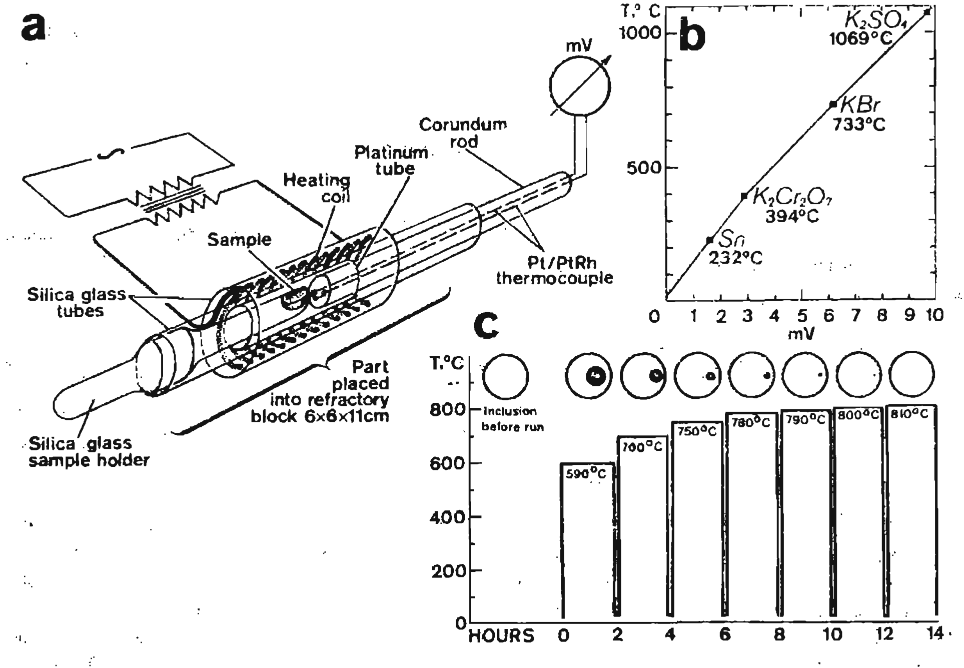


Fig. 1. Quenching method of homogenization of inclusions

a — sketch of microfurnace for quenching metod, **b** — calibration curve for the microfurnace, **c** — series of typical heating/quenching runs for determination of homogenization temperature from temperature of run to the room temperature in about 2 sec. was achieved by throwing hot quartz grain on cold metal plate. Series of heating runs at increasing temperatures with following inclusion checking under microscope approached homogenization of inclusion (Text-fig. 1c). Normal microscope heating stage technique could not be used due to rough surface of quartz grains, too small for polished preparations.

Microscope crushing stage (*Chaixmeca* type) based on the Krogh's (1911) idea and Roedder's (1970) construction, was used for checking of gas presence in melt and gas-liquid inclusions. Cedar oil was used as immersion liquid.

MELT AND GAS-LIQUID INCLUSIONS

Each of the studied crystals bear from one to about twenty large primary melt inclusions (∾ 0.1 mm in size) and from nil to about one hundred of tiny (0.001—0.1 mm) secondary mostly gas-liquid inclusions. Melt inclusions display euhedral or subhedral high-quartz habit (Pl. 1, Fig. 1), but also rounded or spherical ones are common. Rarely melt inclusions bear one (Pl. 1, Figs 1 and 3) or more (Pl. 1, Fig. 2) shrinkage gas bubbles, but majority of them are filled by homogene silicate glass (Pl. 1, Fig. 4). Melt inclusion bearing shinkage bubbles are either the largest inclusions in the grain, or all two or three inclusions present in the grain are with bubbles, even if they are smaller ones. This proves the presence of at least three ways of cooling:

(i) Very rapid cooling: no shrinkage bubbles, perfect supercooling;
(ii) Relatively slow cooling down to certain temperature and then abrupt temperature decrease: shrinkage bubbles only in the largest inclusions;
(iii) Slow cooling over significant temperature interval: all inclusions have shrinkage bubbles.

There is probably the fourth possible way (intermediate between cases *i* and *ii*) when cooling rate was too slow to preclude formation of shrinkage bublles but too rapid to form only one bubble or to join few smaller bubbles into one larger, as it is evidenced by inclusions bearing two or more bubbles.

Some inclusions occur next to rutile and hornoblende crystals, or bear them as trapped minerals (Pl. 1, Figs 5—7). Primary origin of all the above melt inclusions is evidenced by their random distribution mainly in the inner core of crystals and by their arrangement in growth zones (Pl. 1, Fig. 8).

In several quartz crystals, together with melt inclusions, there also occur different types of inclusions. Their habit and distribution suggest them to be coeval with melt inclusions (Pl. 2, Fig. 2), but their filling differs strongly (Pl. 2, Fig. 1 and Pl. 3, Fig. 1). The following types of filling were recognized:

1) Glass partly (Pl. 2, Fig. 3), almost completely (Pl. 3, Fig. 3) or completely altered (Pl. 2, Fig. 4) into presumably layer silicates. Glass often preserved in the parts of inclusion vacuole poorly permeable for altering solutions, whereas the major part of inclusion is completely altered (Pl. 3, Fig. 5);
2) Glass completely removed from inclusion vacuole, next filled with gaseous solution (Pl. 2, Fig. 5), sometimes with slight alteration of the vacuole habit (Pl. 2, Fig. 6);
3) Glass completely removed from inclusion vacuole, vacuole surface slightly corroded or dissolved, inclusion next filled by hydrothermal solution (Pl 3, Fig. 2) of variable gas/liquid ratio (Pl. 3, Fig. 4);
4) Glass preserved only in fragments, but without visible alterations, in the remaining part of vacuole opaque mineral replaced glass (Pl. 2, Fig. 7); this mineral in reflected light appears to be aggregate of subhedral pyrite grains (Pl. 2, Fig. 8).

Anyone of the altered inclusions has trace of former fractures opening the inclusion and later healed, whereas inclusions not affected by cracks preserved unaltered melt filling (Pl. 3, Fig. 6). Thus, the fractures were the ways of circulation of post-magmatic solutions. Depending on the time between cracking and healing of fracture and on solution activity, the former glass filling was altered partly, completely or removed. Cases *2* and *3* should be called the refilling of melt inclusions by pneumatolytic or hydrothermal solutions (Kalyuzhnyi 1971, Kozłowski & Karwowski 1972). The healed fractures are beaded with secondary tiny gaseous or gas-liquid inclusions.

THERMOMETRIC STUDIES

Most of glass inclusions do not bear shrinkage bubbles due to perfect supercooling of silicate melt (Pl. 4, Fig. 1), hence an attempt was made to put the inclusions under conditions favourable for nucleation of the bubbles. Usually 2 hours run at temperature 590—610° C was sufficient for that process but not at lower temperatures (Pl. 4, Fig. 2). That runs submitted also information that at about 600° C silicate melt filling inclusions was liquid of sufficiently low viscosity to form shrinkage bubbles.

If the runs intending to obtain shrinkage bubble started at temperature 650—680° C, next decreased slowly to about 600° C, formation of single bubble was observed (Pl. 4, Figs 5—6), contrary to relatively short calcination only at 600° C, when up to twelve bubbles appeared. Several more heating runs at increasing temperatures approached homogenization of inclusions, which occurred at very narrow temperature range 790—810° C ± measurement error equal 5° C (Pl. 4, Fig. 3). Few repeated homogenization runs or one heating up to temperature exceeding homogenization temperature (*Th*) over an interval of 50—60° C caused decrepitation of inclusion and separation of hundreds of tiny bubbles of gas due to pressure decrease, i.e. the boiling of magma in inclusion scale (Pl. 4, Figs 4 and 7—8).

In few cases decrepitation has been achieved at temperature as low as 630—690° C with the same effect of volatile separation. Since those inclusions contained several gas bubbles before runs, their preservation after "boiling" proves, that homogenization was not reached (Pl. 4, Figs 9—10 and 12—13). Chips of glass gotten by "boiling", subsequently calcinated at temperature of melting of inclusion filling (600° C) or even at 700° C, did not melt (Pl. 4, Fig. 11), being the evidence of strong influence of volatile content on melting (or consolidation) temperature of magma.

CRUSHING STAGE STUDIES

The use of microscope crushing stage for opening of the individual inclusions submitted some data on pressure in gas bubbles. Melt inclusion with shrinkage bubble formed during five-hour calcination at 675° C, on crushing displayed increase of bubble diameter about five times. Thus, the pressure of volatiles in shrinkage bubble significantly exceeded 1 atm at room temperature, being even higher at temperature close to *Th*.

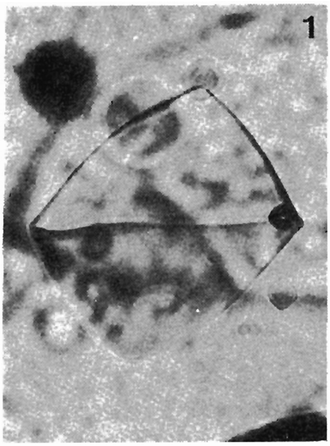
On the other hand, all studied inclusions refilled by gas or liquid solution, on crushing either produced bubble smaller than that present in inclusion (Pl. 5, Figs 1, 3, 7 and 8) or of the same size (Pl. 5, Figs 5—6). Hence, pressure of volatiles at room temperature in refilled inclusions should be $\leqslant 1$ atm, and gas bubbles often might be filled in significant part by aqueous vapor. Crushing stage studies proved also that inclusions with large bubbles looking like coeval with melt ones cannot be gas-melt inclusions formed due to natural magma boiling, since on crushing meniscus in inclusion moves (Pl. 5, Figs 2 and 4), being liquid at room temperature. Also some inclusions filled by products of glass alternation, did not bear gas in vacuole (Pl. 5, Figs 9—12), being thus attributable to cold-water alterations, may be in the secondary (sedimentary) deposit.

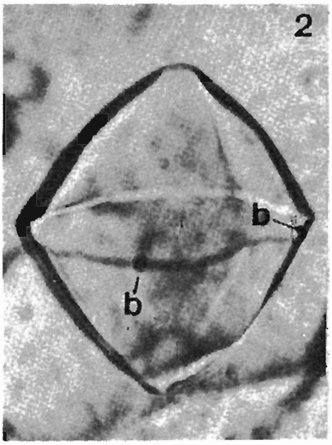
PROBLEM OF "MAGMATIC CORROSION"

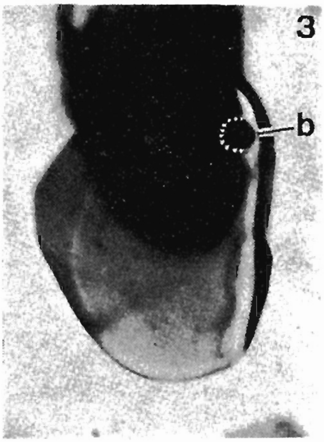
Many of the studied quartz crystals exhibit embayments (Pl. 6, Fig. 1) usually attributable to reactions phenocrysts-melt or partial dissolution or etching of phenocrysts in magma, i.e. to phenomena generally called the magmatic corrosion. Such interpretation is very common (*see e.g.* Siemaszko 1978, Fig. 7; reproduced here in Pl. 6, Fig. 3), although with no evidences in each peculiar case, but often with the arbitrary statements that the "*embayments... evidently arose from magmatic corrosion*" (Kühn & Scharm 1978, p. 434 and Fig. 1 in p. 442). The author's intention in the present chapter is to recall the readers' attention to another and probably more reasonable interpretation of the embayment nature.

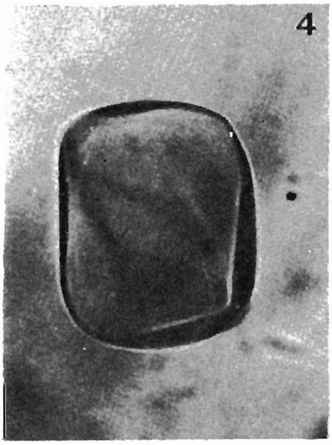
Careful studies of the embayments frequently reveal salient similarity of their habit to the shape of melt inclusions, occurring in the same mineral grain (Pl. 6, Fig. 2). Rounded or spherical inclusions occur together with flask- or bulb-shape embayments, inclusions-negative crystals are accompanied by the flat-faceted embayments, irregular inclusions and embayments also exist together (Pl. 6, Figs 1—10; *cf. also* Text-fig. 2 *in* Kozłowski 1975). Very thorough studies performed by Lemmlein (1973a) revealed also another important feature: in the wall of embayment closest to the centre of crystal, often tiny crystals of biotite, plagioclase or magnetite may be found. This fact makes invalid the supposition that embayments have formed by corrosion of quartz grain, and it proves that origin of embayments, similarly as of many melt (or other fluid) inclusions, is due to inhibition of crystal growth by minute mineral grains sticking to the face of growing crystal. Thus, the embayments should be considered as features of growth, not of destroying of crystal. They may be called the effects of either dendritic growth of crystal or incomplete sealing of melt inclusions. Sometimes interpretation of the embayment origin is in surprising contradiction with the enclosed photographs. Rinne (1923, Fig. 163 in p. 73) presented an olivine grain (reproduced here in Pl. 6, Fig. 4) called "*magmatically corroded*" which develops typical weak cleavage not affected at the grain boundary by any corrosion, and embayments displaying together with melt inclusions a pattern perfectly outlining growth zones. Magmatic dissolution or corrosion might preferably attack crystals along the cleavage planes as the weakest direction in crystal, like hydrothermal etching found in microclines (Kozłowski 1978, Pl. 13, Figs 1—2). However, olivine with similar habit (Pl. 6, Figs 5—6) was also correctly interpreted as "*skeletal crystals*", i.e. growth forms (Zavaritskiy 1955, Fig. 204 in p. 427). Some authors preferred neutral, descriptive names (Pl. 6, Fig. 7), calling crystal wtih embayments "*quartz pierced with »worm paths«*" (e.g. Polovinkina 1966, Fig. 256 in p. 290). Lemmlein 1973b) discussed the evidences proving that quartz with embayments appears almost exclusively due to skeletal growth (Pl. 6, Figs 8—9). Unfortunately, many published drawings of the "corroded crystals" are so schematic (*e.g.* Correns 1966, Fig. 295 in p. 192; Rinne 1926, Fig. 173 in p. 79; Rosenbusch & Osann 1937, Fig. 17 in p. 68). that make impossible to consider their true nature.

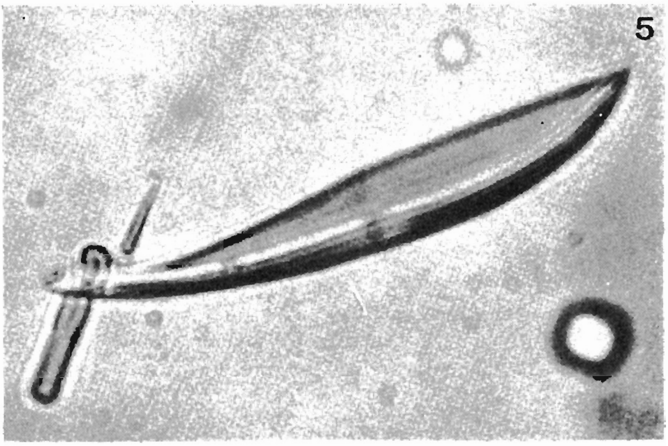
Interesting psychological aspect of the "corrosion problem" may be presented as follows: imagination of ardent highly active magma is so dramatic, that anyone accepts formation of rather strange "corrosion patterns" by this high-temperature melt. However, nobody has ever con-

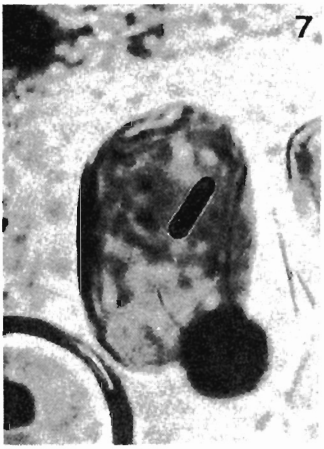




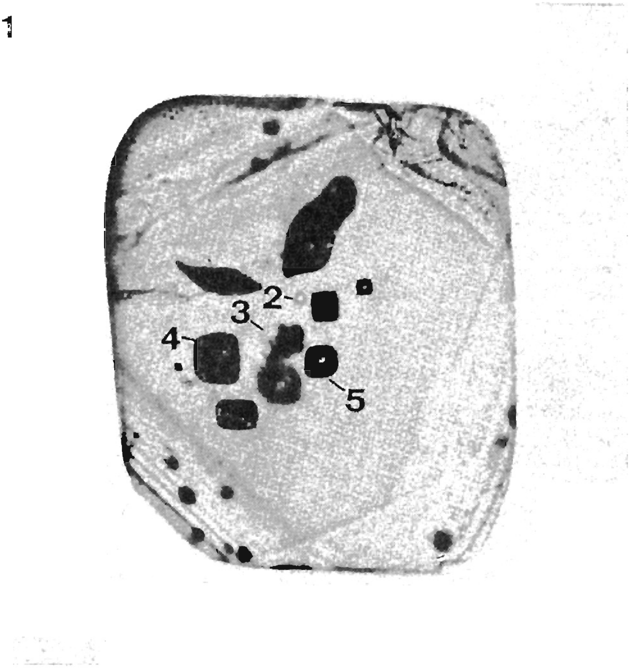


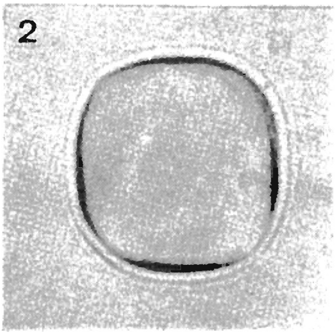


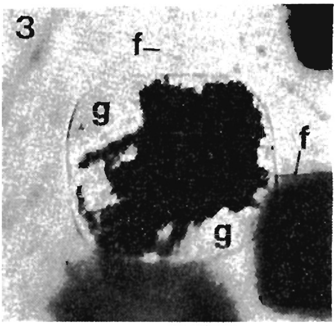


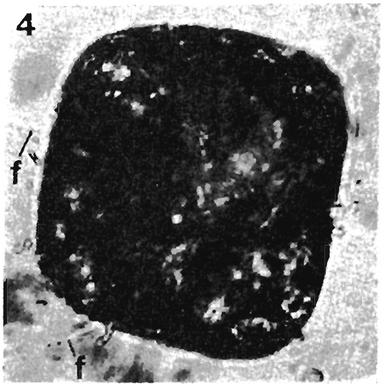


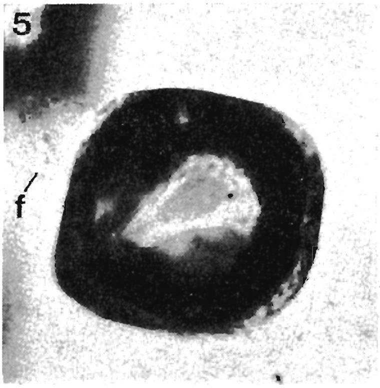
1 — Euhedral melt inclusion with one shrinkage bubble; × 300
2 — Same, with two shrinkage bubbles (*b*); × 300
3 — Subhedral melt inclusion with one shrinkage bubble (*b*), partly shadowed by overlying inclusion; × 300
4 — Melt inclusion without shrinkage bubble; × 400
5 and 6 — Melt inclusions with rutile crystals; × 300
7 — Same, with hornblende; × 400
8 — Primary melt inclusions in growth zone of quartz crystal; × 60

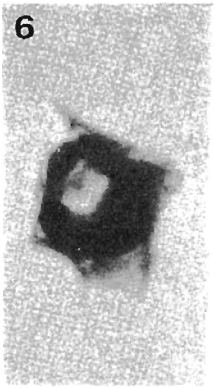


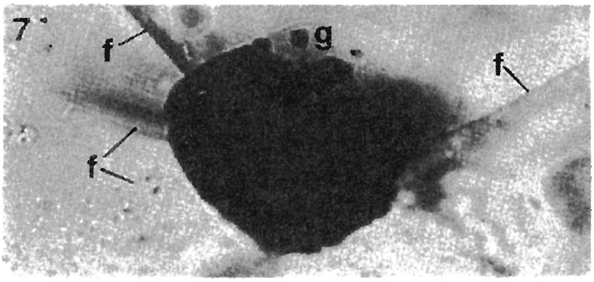


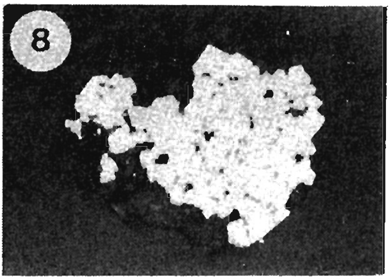






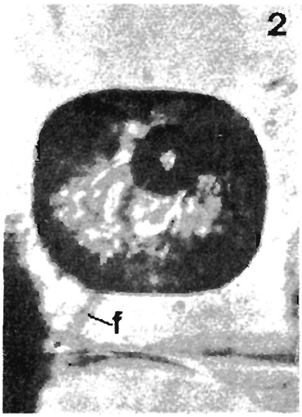


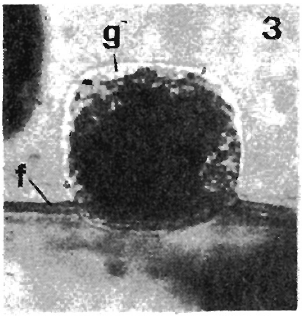


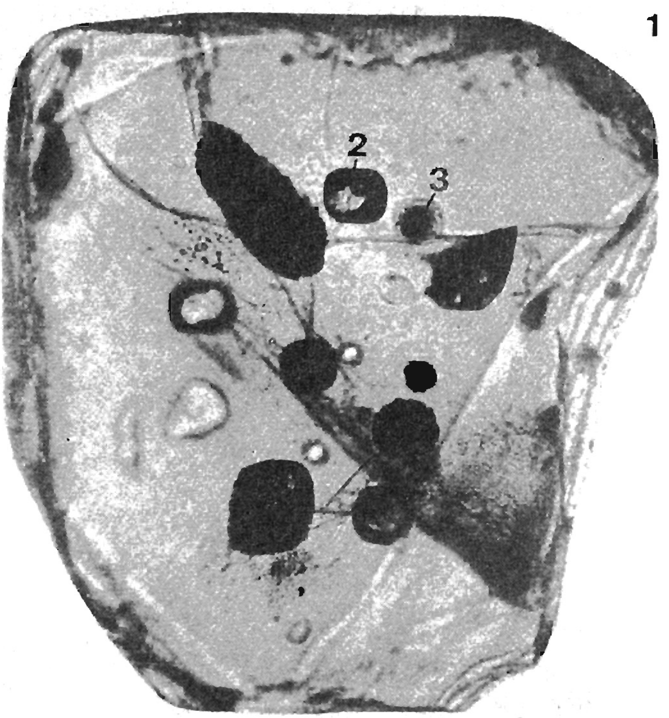


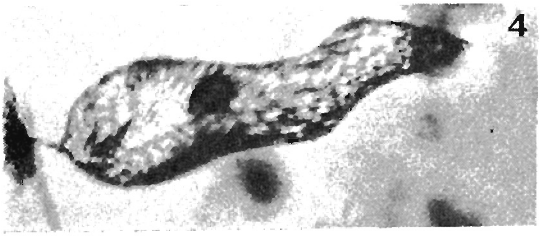
1 — Quartz grain bearing melt, altered and refilled inclusions in the inner core (2—5 — inclusions presented in Figs 2—5 of this plate); × 60
2 — Melt inclusion; × 1000
3 — Melt inclusion partly altered in ?layer silicates; × 300
4 — Former melt inclusion with filling completely altered in ?layer silicates; × 400
5 — Former melt inclusion refilled by gas solution; × 400
6 — Same, inclusion vacuole slightly changed during refilling: × 600
7 — Former melt inclusion mostly refilled by pyrite aggregate (*black*), glass partly preserved, transmitted light; × 350
8 — Same, reflected light; × 350

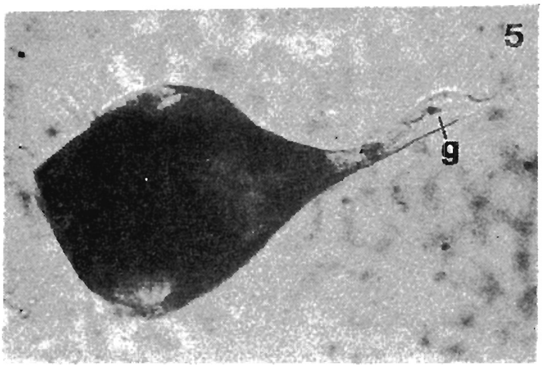
g — silicate glass, f — fracture partly or completely healed

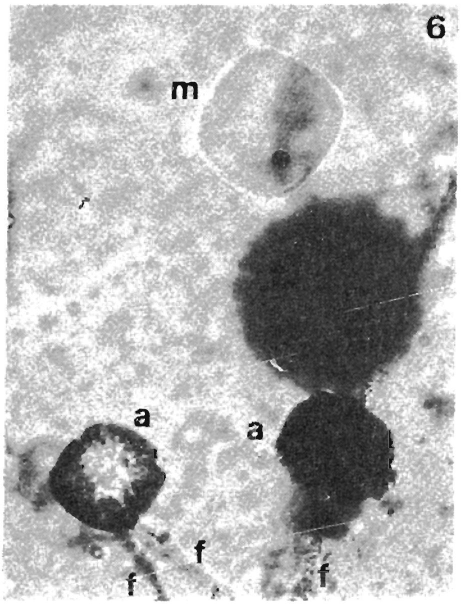












1 — Quartz grain bearing melt, altered and refilled inclusions in the inner core (2—3 — inclusions presented in Figs 2 and 3 of this plate); × 60

2 — Former melt inclusion refilled by hydrothermal solution; × 250

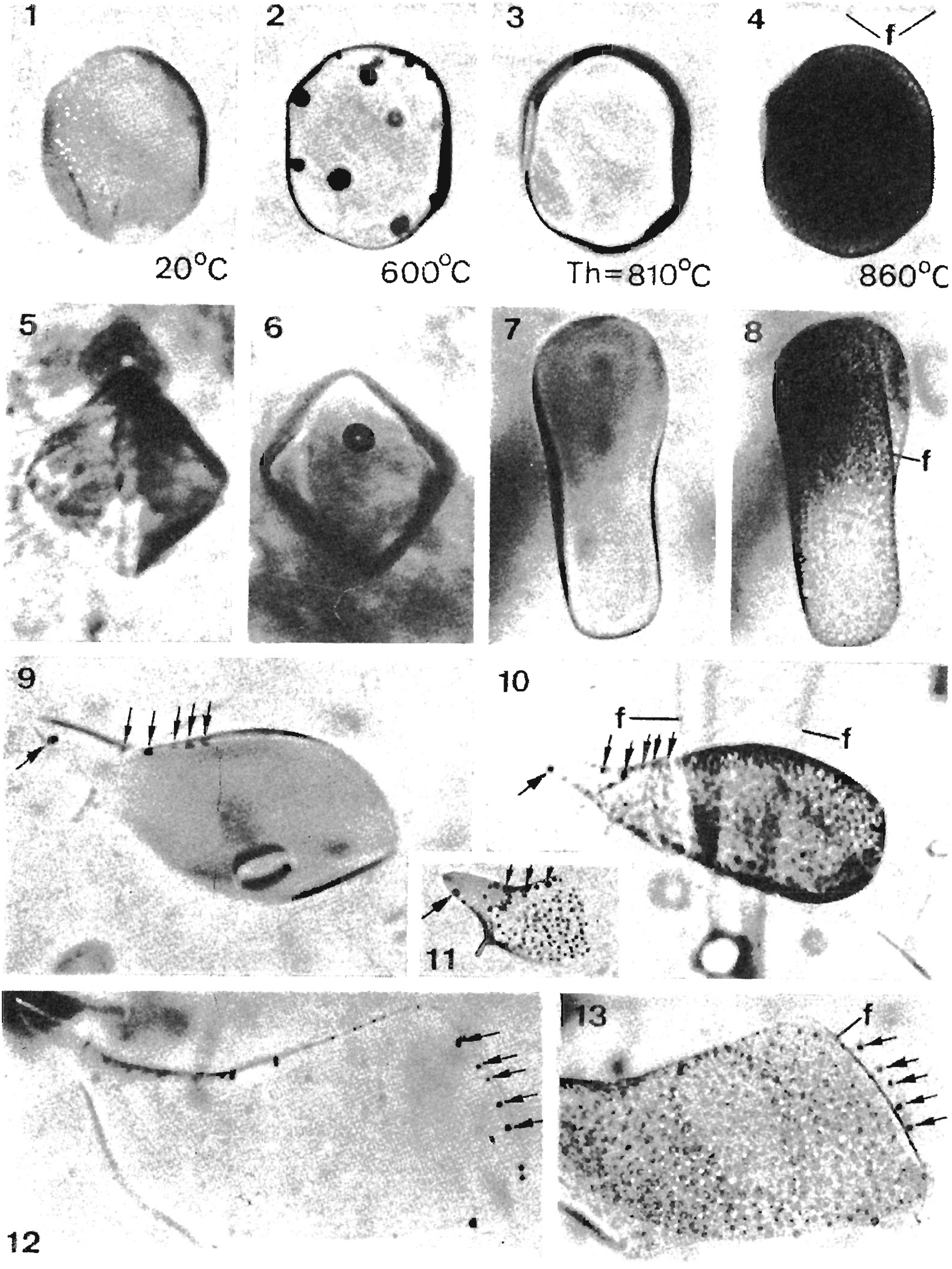
3 — Melt inclusion with filling almost completely altered in ?layer silicates; × 250

4 — Former melt inclusion refilled by hydrothermal solution, vacuole walls etched; × 300

5 — Melt inclusion with filling altered in ?layer silicates, glass (*g*) preserved in the very narrow part of vacuole; × 200

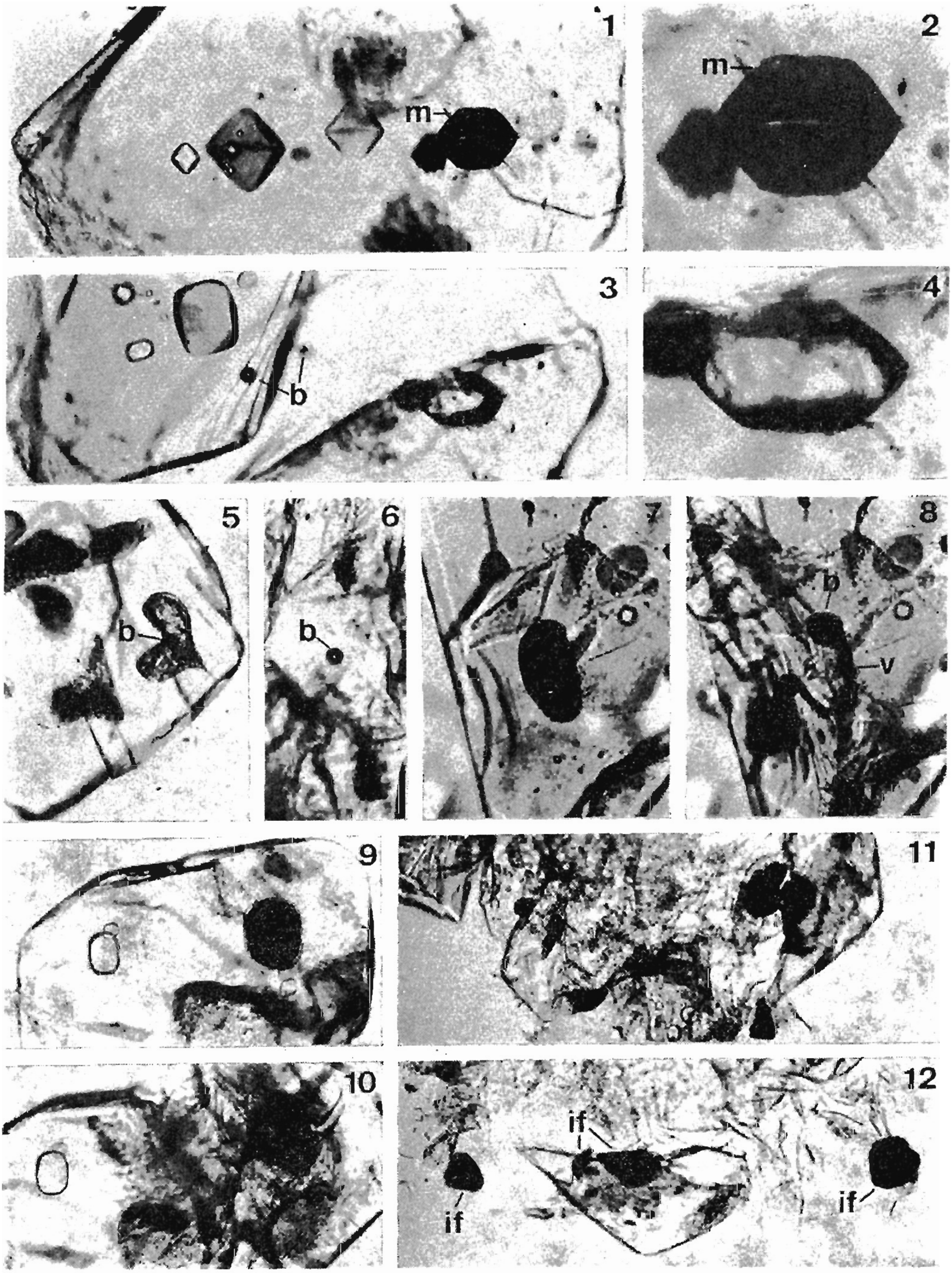
6 — Melt inclusions: fresh (*m*) with shrinkage bubble and altered (*a*) after opening by cracks; × 150

f — fractures partly or completely healed



1 — Melt inclusion before heating run; **2** — Same, after initial calcination and rapid cooling, with several shrinkage bubbles formed; **3** Same, after homogenization; **4** — Same, after decrepitation; **5** — Melt inclusion before run; **6** — Same, after initial calcination and slower cooling, with one shrinkage bubble; **7** — Melt inclusion before run; **8** — Same, after decrepitation, **9** — Inclusion with six small shrinkage bubbles before run; **10** — Same, after decrepitation; **11** — Piece of glass of the inclusion from Fig. 10 after calcination at 700° C; **12** — Melt inclusion with numerous small shrinkage bubbles; **13** — Same, after decrepitation

All micrographs × 300; f — fracture formed on decrepitation; some shrinkage bubbles visible in the same place before and after calcination are arrowed



1 — Gas inclusion before crushing, meniscus (*m*) poorly visible; **2** — Same, close-up view; **3** Same, after crushing (*b* — gas bubble released from the inclusion); **4** — Same as in Fig. 3, close-up view; **5** — Gas-liquid inclusion before crushing; **6** — Gas bubble (*b*) released from the inclusion in Fig. 5; **7** — Gas inclusion before crushing; **8** — Same, after crushing, (*b* — gas buble, *v* — wall of the inclusion vacuole); **9** — Altered inclusion before crushing; **10—12** — Same, stages of crushing, no gas bubble (*if* — inclusion filling, probably smectite aggregate)

All micrographs × 100, except of Figs 2 and 4 which are × 240

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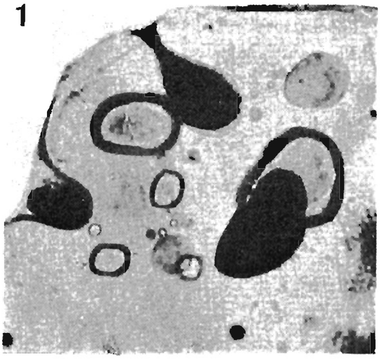

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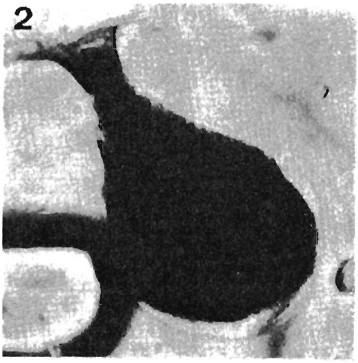

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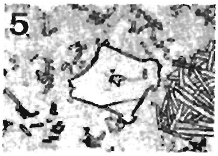

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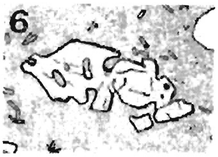

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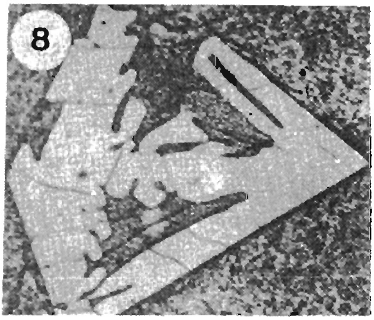

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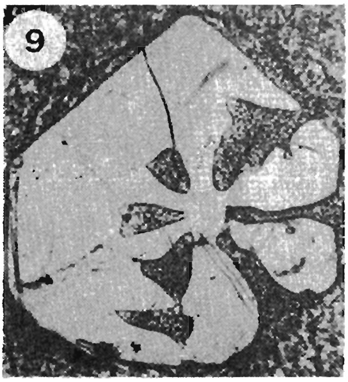

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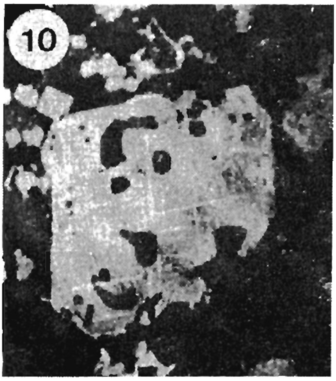

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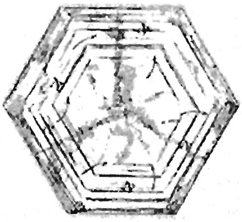

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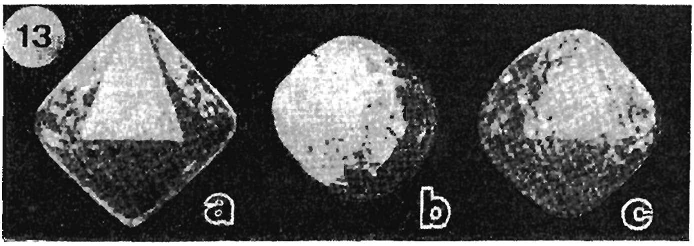

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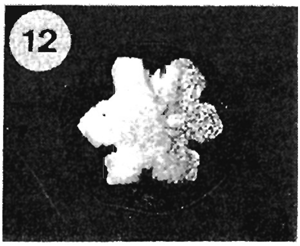

nected with corrosion the identical embayments in maghemite crystals (Pl. 6, Fig. 10) formed in dumps (Lazarenko & al. 1975, Fig. 111a in p. 128).

The term "corrosion" is used in sense of chemical degradation of solids, hence in magmatic phenomena this name should be reserved for chemical assimilation of crystals by magma. However, assimilation of crystals have to cause the changed composition in the nearest neighborhood in surrounding medium at least until the crystal exists. In fact, various monomineral xenoliths in magma form on assimilation rims of newly crystallized minerals (*e.g.* quartz + basalt melt → pyroxene rim, *etc.*) frequently with glass (*cf.* Lacroix 1893, p. 19). Crystals dissolving in magma used to be deeply etched (McBirney 1979, Fig. 10—4 in p. 317), but the etching traces are *V*-shaped not bottle-shaped and etching develops along cleavage planes. The bottle-shaped embayments should fill quickly with melt saturated with dissolved matter and being in equilibrium with crystal, and thus any further increase of embayment should be precluded.

Sometimes the possibility of etching of deep and narrow channels in quartz is presumed on the basis of picture (Pl. 6, Fig. 12) published by Lacroix (1901, Fig. 82 in p. 111). However, this pattern of etching with hydrofluoric acid has been achieved for quartz crystals (Pl. 6, Fig. 11) which contained numerous anhydrite inclusions in narrow zone perpendicular to $(10\bar{1}0)$ and for this reason etched easily (Lacroix 1901, Fig. 29 in p. 44).

PLATE 6

1 — Embayments and melt inclusions (one altered), Kowala specimen; × 100
2 — Same, close-up view of embayment; × 300
3 — "Corrosion embayment" in quartz grain, Fore-Sudetic monocline; × 30 Siemaszko 1978, Fig. 7)
4 — "Magmatically corroded" olivine in basaltic glass from Sesebühl near Dransfeld, Hannover (*after* Rinne 1923, Fig. 163 in p. 73)
5 and 6 — Skeletal olivine from lavas of volcanoes Uyun-Kholdongi, Mandzhuria; × 50 (*after* Zavaritskiy 1955, Fig. 204 in p. 427)
7 — Quartz grain with "worm paths" in liparite, Arvidsjoer, Sweden, × 5 (*after* Polovinkina 1966, Fig. 256 in p. 290)
8 and 9 — Skeletal quartz from obsidian, Berezovka River, Kolyma area, USSR; 8 taken × 100 and 9 taken × 140 (*after* Lemmlein 1973b, Figs 7 and 8 in p. 23)
10 — Maghemite from dump, Donets Basin, Ukraina; × 140 (*after* Lazarenko & *al.* 1979, Fig. 111a in p. 28).
11 — Quartz from Triassic clays, Souree de la Salz, Aude, France, section in (0001) plane (*after* Lacroix 1901, Fig. 29 in p. 44)
12 — Specimen from the same location, etched with HF (*after* Lacroix 1901, Fig. 82 in p. 111)
13 — Quartz phenocrysts from quartz porphyry, Samshvildo near Tbilisi, Georgia: a — fresh crystal, b — globular partially melted crystal, d — crystal partially melted and subsequently regenerated to subhedral habit (*from* Betekhtin 1950, Fig. 305 in p. 437, *after* Lemmlein)

Crystals may be also destroyed by dissolution without chemical reactions in undersaturated magmatic melt due to its increasing temperature. In this case no additional mineral phase appears, but faceted crystals become rounded or globular (Pl. 6, Fig. 13; *taken from* Betekhtin 1950, Fig. 305 in p. 437). The discussed "corrosion", here called correctly the *partial melting*, may be also expected for olivine crystals if affected by increasing temperature, but the crystals being products of partial melting of substance on the crystal edges and faces should get globular not dendritic habit. Presumably, traces of partial melting of olivine crystals may be recognized among meteorite olivines (Text-fig. 2), but it is necessary to remember the second possibility, that tiny faces on globular crystal may also form due to recrystallization of the crystal sphere to euhedral habit.

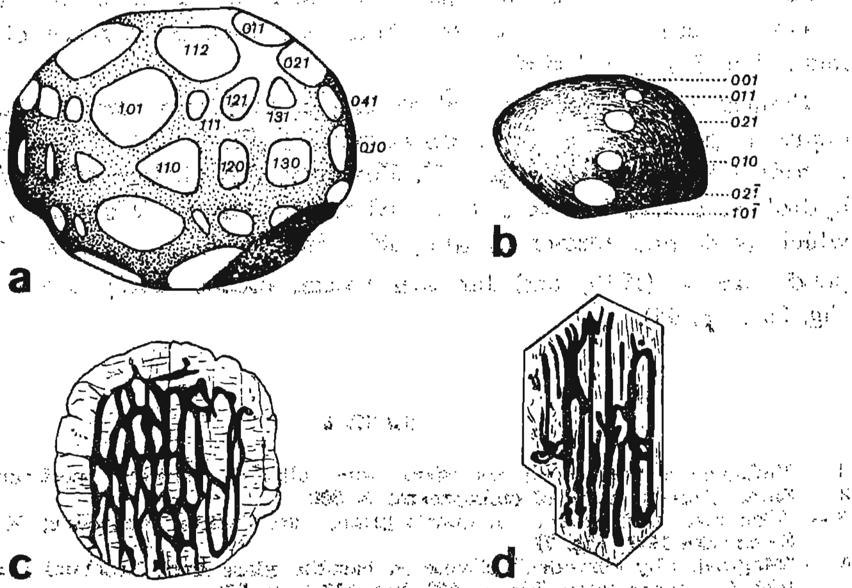

Fig. 2. Habit of the olivine crystals from meteorites

a — globular crystal, location unknown (*after* Lazarenko 1979, Fig. 35g in p. 254); **b** — globular crystal from iron meteorite, Krasnoyarsk, Siberia; **c** — section of the globular crystal from stony meteorite, Mezö-Madaras, Hungary (note the excentric pattern of the inner melt-inclusion-rich core and the outer inclusion-free zone, what may be also attributed to partial melting of the crystal); **d** — section of the euhedral crystal from chondrite, location unknown: the inner core bearing glass inclusions is surrounded by the outer inclusion-free zone of constant thickness, no melting signs (*after* Tschermak & Becke 1931: *b* = Fig. 9, *c* = Fig. 11, *d* = Fig. 10 in p. 812).

Conclusion on magmatic corrosion of phenocrysts is of important consequence, since it proves either rapid change of chemical composition of melt, i.e. serious evolution of magmatic chamber, or xenogenic origin of phenocrysts. Any suggestion of partial melting of phenocrysts causes also acceptation of distinct temperature increase of magma. Both phenomena, the magma evolution and the temperature increment, should influence strongly the magmatic process, thus such conclusions have to be made on the basis of undoubted observations. In this context the almost ninety-year-old statement of Zirkel (1893, p. 754) seems to be still valid: "The term *corrosion* has been used too frequently: surely it is not justified to see in any morphological irregularity, in any embayment of crystal the result of external mechanical or chemical deformation, if anybody does not take into account the possibility of irregular growth".

MECHANISM OF THE VOLCANO ERUPTION

The performed studies submitted evidences that pyroclastic quartz from the Lower Carboniferous of Kowala in the Holy Cross Mts crystallized at temperature above 800° C from magma rich in volatiles, so that volcano(es) which erupted pyroclastic material should be highly explosive. There is no evidence that pyroclastic material has come either from one or from several eruptions, or even from more than one volcano, thus the following conclusion will be based on the simplest but a little arbitrary presumption: one volcano and one eruption, supported by narrow *Th* range. Some quartz phenocrysts came on eruption from liquid magma and they cooled during explosion from 800° C down to $\leqslant 600°$ C in few seconds without producing shrinkage bubbles in inclusions. Other quartz phenocrysts cooled slower either in the volcano neck before explosion or during explosion (probably both possibilities existed, since various observed shrinkage bubbles might form in minutes, hours and days). No overheating up to temperatures significantly exceeding 800° C would be anticipated when phenocrysts were under surface conditions i.e. under low pressure before eruption, because it should cause common decrepitation and boiling of inclusions which are not observed in the studied crystals.

There were also parts of rock in the volcano already cooled and submitted to pneumatolytic and hydrothermal activity, probably strongly altering volcanic rocks. Gas and gas-liquid inclusions looking like coeval with melt ones and formed due to melt-water solution immiscibility, are not coeval in fact, because of large pressure difference in shrinkage bubbles of melt inclusions and in gas-liquid inclusions. In case of a coeval origin the pressure should be very similar. Gas-liquid inclusions with *Th* ≈ 200° C, if formed at 800° C (coeval with melt inclusions) would require presence of very high pressure about 10 kb, when pure water filling is assumed (Fisher 1976). Consequently, refilling of melt inclusions by pneumatolytic and hydrothermal solutions migrating along fractures formed due to tectonic movements during eruption is rather acceptable.

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A. KOZŁOWSKI

INKLUZJE STOPU W KWARCU PIROKLASTYCZNYM Z UTWORÓW KARBONU W KOWALI ORAZ PROBLEM KOROZJI MAGMOWEJ

(Streszczenie)

Przedmiotem pracy jest rekonstrukcja warunków krystalizacji fenokryształów kwarcu, występujących jako materiał piroklastyczny w utworach dolnego karbonu Kowali w Górach Świętokrzyskich. W oparciu o badania inkluzji stopu krzemianowego metodą przechładzania (fig. 1 oraz pl. 1—4) oznaczono temperaturę krystalizacji na około 800° C i stwierdzono, że powinna ona być bliska temperaturze erupcji. Wykazano, że magma była bogata w składniki lotne, a badając zawartość fazy gazowej poszczególnych inkluzji za pomocą metody otwierania ich pod mikroskopem (pl. 5) stwierdzono odmienny skład i ciśnienie części lotnych na etapie magmowym i pomagmowym. Przedyskutowanie problemu tzw. „zatok korozyjnych" (fig. 2 oraz pl. 6) doprowadziło do wniosku, że nie świadczą one o chemicznej korozji magmowej ani o rozpuszczaniu fenokryształów w magmie, lecz o zaburzeniach ich sieci w trakcie wzrostu.