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THE XENOLITHS OF « CENERIGNEISSES » (*)

Summary. — The « Cenerigneiss », an important rock type of the « Serie dei Laghi » (Lake Maggiore, Northern Italy), contains abundant calc-silicate xenoliths with a more or less continuous rim of fine grained gneiss. Zones of different mineral composition may be observed on petrographic examination: *core* with: quartz, epidote, garnet, (carbonate), sphene, clinopyroxene; *pyroxene zone* with: quartz, epidote, clinopyroxene, sphene; *amphibole zone* with.: quartz, amphibole, sericitic aggregates, epidote, sphene; *wall zone* with quartz, sericitic aggregates, biotite, apatite, garnet.

Though the mineral assemblages and the succession of zones are similar to those quoted in the literature regarding calc-silicate xenoliths of migmatic rocks, the present internal structure seems mostly related to a later strong deformation act followed by a static recrystallization. Also the contact with the enclosing gneiss is clearly later than the formation of the zoning: therefore the influence on the composition of the gneiss near the contact is practically absent.

Riassunto. — I « Cenerigneiss » sono un importante tipo litologico della « Serie dei Laghi » (Lago Maggiore, Nord Italia) e contengono numerosi inclusi a silicati di calcio con anelli più o meno completi di gneiss a grana minuta. Per mezzo di uno studio petrografico sono distinguibili zone di diversa composizione mineralogica: *nucleo* a quarzo, epidoto, granato, (carbonato), titanite, e pirosseno monoclino; *zona pirossenica* con quarzo, epidoto, pirosseno monoclino e titanite; *zona anfibolica* a quarzo, anfibolo, plaghe sericitiche, biotite, apatite, granato.

Sebbene la associazione mineralogica e la successione delle zone sia del tutto simile a quella stabilita da altri AA., per inclusi a silicati di calcio in rocce migmatiche, le strutture interne che si rinvengono ora sembra siano da mettere in relazione con una forte e tardiva deformazione seguita da una ricristallizzazione statica. Anche il contatto tra la roccia incassante e l'incluso è posteriore alla zonatura; perciò l'influenza sulla composizione dello gneiss vicino al contatto è praticamente assente.

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Introduction.

One of the most interesting rock types of the « Serie dei Laghi » is certainly the « Cenerigneiss »; throughout its zone of occurrence this rock shows very particular mesoscopic and microscopic characters which were the reason for the detailed investigations of the many petrographers who studied the gneisses of the « Serie dei Laghi ».

The name was given by REINHARD (1934) as these rocks crop out near the Ceneri pass, and it was later on conserved by BÄCHLIN (1937) and recently by BORIANI (1968).

The « Cenerigneiss » crop out in a vast area in the Sottoceneri region (Tessin), where a detailed petrografic survey was done by BÄCHLIN (1937); his data, together with those of several other Swiss petrographers, were used by REINHARD (1964) for the geologic mapping of the entire Sottoceneri zone which appeared also in the Swiss Geologic Map. The presence of « Cenerigneisses » on the western shore of Lake Maggiore was previously quoted by BÄCHLIN (1937) on the basis of specimens from Ponte Casletto (Val Grande) supplied to him by Novarese; also REINHARD (1964) mentioned the « Cenerigneiss » of Ponte Casletto and another occurrence near Cannobio. Widespread occurrences of « Cenerignisses » in this area were reported by BORIANI (1968) in the Ponte Casletto-Pian Cavallone zone; in a new survey BORIANI (1970 b) reveals the wide diffusion of this rock on the western shore of Lake Maggiore.

Mesoscopic and microscopic features of « Cenerigneiss ».

The « Cenerigneiss » is a schistose and more or less lineated to massive rock, showing a yellowish grey color with reddish coatings; it is medium to fine grained and contains a great quantity of xenoliths, highly variable in shape and size.

The mineral assemblage is: quartz, plagioclase, biotite, muscovite $\pm$ K-feldspar $\pm$ garnet $\pm$ kyanite $\pm$ sillimanite with as constant accessories apatite, zircon, opaque minerals.

« Cenerigneisses » have a very particular microscopic appearance and differ from the other metamorphic rocks in their strongly heteroblastic texture. The fundamental minerals, except quartz, are present in two different generations: the former of pre-kinematic origin, the latter of post-kinematic.

The *quartz* is present as flattened lenses in the schistose, as elongated or stubby grains in the other types, always divided into subgrains with slight optical disorientation; this character suggests an essentially syn-kinematic origin.

Plagioclase and *micas* are present as tiny polygonal and respectively idioblastic grains forming monomineralic aggregates sometimes containing large deformed crystal of first generation.

The *K-feldspar* is only seldom present because it is more or less completely replaced by non polygonal myrmekitic plagioclase or by quartz-plagioclase intergrowths; polygonal aggregates of second generation are very rare among the replacement products.

Garnet and *kyanite* form small grains included in biotite or in a fine grained muscovite matrix.

Petrogenesis.

Bächlin (1937) considered the « Cenerigneiss » as « Mischgneise » on account of their migmatic appearance, and attributed the microstructure to an unspecified blastocataclastic process.

For Reinhard (1964) the « Cenerigneisses » are true paragneisses and their texture represents a frozen initial stage of blastesis.

Boriani (1968) refers the non-equilibrium mineral assemblage and the presence of xenoliths to an anatectic phenomenon and the texture to the restored metamorphic condition after the melting. On the basis of more detailed studies (Boriani 1970 a e b) the author confirms the hypothesis of the anatectic origin and emphasizes the presence of a later phase of intense deformation which caused the present gneissic texture of the rock; after this event an important phase of static recrystallization occurred and this is responsible for the second generation of fine grained minerals.

The age of anatexis is thought to be Caledonian; the final static phase and perhaps the strong intermediate deformation is referred to the Hercynian orogenesis.

Calc-silicate xenoliths.

The presence of xenoliths is a typical feature of « Cenerigneisses »; their shape is highly variable and related to the texture of the gneiss; from flattened lenses in schistose to subspherical bodies in the massive types. Their long axes range from a few cm to two or seldom more meters in length.

In the area under consideration all the xenolith types described by BÄCHLIN (1937) in Sottoceneri may be found; both those consisting of fine grained gneiss and those consisting of calc-silicate rock sometimes surrounded by a fine grained gneiss shell.

It is noteworthy that, whatever their composition, the transition to the enclosing rock is very sharp; in the calc-silicate xenoliths with a shell of fine grained gneiss, this more or less completely surrounds the core, while the position of the contact surface does not depend upon the internal zoning of the xenolith.

When several xenoliths lie in continuity along the schistosity plane their long axes may be parallel or variously rotated; sometimes between them, in the pressure shadows, quartz concentrations appear, suggesting division due to boudinage.

Besides the frequently observed presence of fine grained gneiss shells, the xenoliths are generally zoned; zoning may be seen by the color variation from the core to the outer shell: reddish core shading to pink, grayish green, becoming dark in color. The central core appears on the outcropping surface with scattered small holes probably caused by the solution of a carbonate.

Generally the selective solution permits us to recognize the internal structure of the core; only once was a planar arrangement of parallel carbonate zones found; they probably represent a relic of S_0.

Detailed microscopic investigation were carried out on two xenoliths both from the main level of « Cenerigneisses »; the former from the Cadorna road near M. Bavarione (co-ord. 68149826), the latter from a locality near Bracchio (co-ord 56529092) in the lower Ossola Valley. This point is situated on the SW end part of the outcrop area of « Cenerigneisses » near the Pogallo fault (BORIANI 1970 b).

The first specimen is a xenolith with a nearly ovoidal cross section of about 45×30 cm (fig. 1). The outcrop section is cut at an angle of 20° to lineation while the long axis is almost parallel to the schistosity plane; the internal structures suggest a rotation of the xenolith.

It is divided into rather continous zones parallel to the schistosity; the core zone is more or less intensely colored and is caracterized by the presence of small cavities and decreases in thickness towards the periphery. It is enclosed between two pinkish-grey zones with grey spots; one of these is cut obliquely by a narrow white vein. The contact is a surface of differential shear movement. It is to be noted that in this specimen the zones of different composition do not form complete shells around the core but nearly parallel layers which are cut by the contact; further they are discordant with the enclosing gneiss.

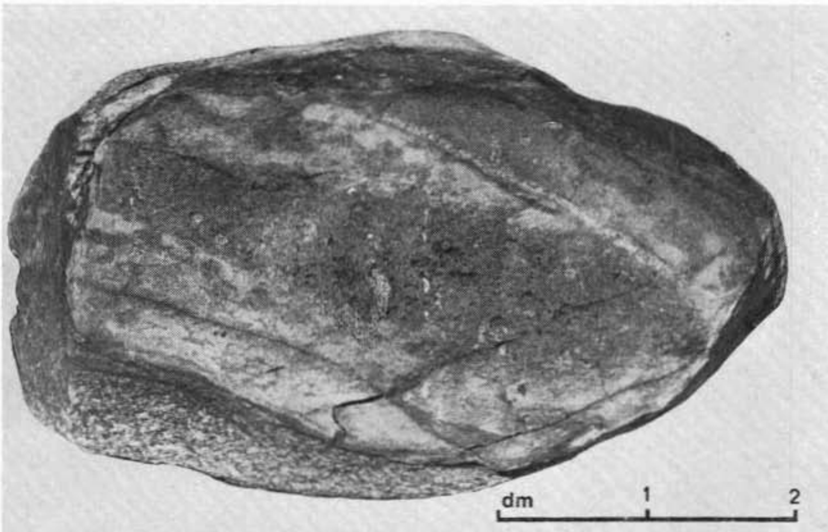

Fig. 1. — Specimen 1 (M. Bavarione); it may be noted that the form of the various shells is clearly independent from the external shape of the xenolith.

Outlines of xenoliths composition:

core with medium grain
mineral assemblage: quartz, epidote, garnet, (carbonate), sphene, and clinopyroxene in the outer part;

pyroxene zone with medium grain and variable thickness: from 6 to 10 cm
mineral assemblage: quartz, epidote, clinopyroxene, sphene;

amphibole zone: whith fine grain and thickness about 1 cm
mineral assemblage: quartz, amphibole, sericitic aggregates, epidote in the innermost part, sphene;

wall zone (transition to the gneiss): fine grain and thickness of about 3-5 mm
mineral assemblage: quartz, sericitic aggregates, biotite, apatite, garnet, opaque minerals.

The « Cenerigneiss » immediately near the contact has a normal mineralogic composition. It is possible to observe zones with polygonal plagioclase polysynthetically twinned with rare muscovite (fig. 2).

Furthermore, in a section cut in the pressure shadow, very fine grained aggregates of sometimes twinned plagioclase may be noted.

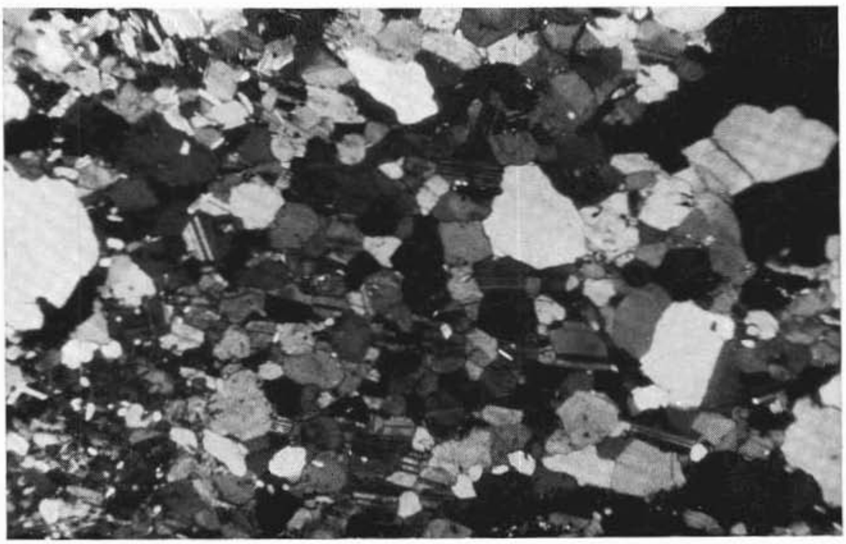

Fig. 2. — The granoblastic polygonal plagioclase of the « Cenerigneiss », near the contact with the xenolith, shows polysynthetic twinning, while it is normally untwinned. Crossed nicols 60 ×.

The second specimen is formed by an ovoidal body of about 60×25 cm flatter then the former; it is possible to note three dark green layers, two external and less continuous intermediate zone, separated by clear green layers with coarse grained, pinkish nuclei and with large spots of amphibole and quartz.

The differences from the first xenolith may be summarized as follows:

a) lack of a reddish core with small hollows;

b) repetition of the clear and the dark colored zones;

c) large amphibole crystals in the innermost part;

d) considerable thickness of the wall zone (4-5 cm);

e) the presence in the outer zone of small and very tight folds with axial plane parallel to the xenolith margin.

At the microscopic examination it is possible to note that:

f) amphibole is very widespread in the dark zones;

g) the core and the pyroxene zone are absent;

h) the large crystals that can be seen mesoscopically often contain big deformed relics of 1st generation amphibole; they are surrounded by small aggregates showing idiotopic texture.

Minerals.

The *quartz*, always present, shows variable grain increasing in size from the peripheral to the innermost zones. It is always clear with curved boundaries in the outer zone, straighter in the core. Extinction is ondulose.

Epidote is present as rounded grains sometimes divided into subgrains colorless or faintly brown, with high relief and anomalous interference colors, while in the second specimen often shows a clear rim (the nucleus is always cloudy) with high interference colors (fig. 3); polysynthetic twinning present. In the second specimen cleavage is particularly evident. $2V_x = 72°\text{-}96°$.

Amphibole is present as idioblastic or subidioblastic prysmatic crystals faintly pleocroic: X = colorless, Y-Z = clear greenish yellow. $2V_x = 80°\text{-}84°$; $Z^\frown c = 16°\text{-}20°$; often showing (OIO) twinning. In the second specimen large porphyroblasts of highly deformed amphibole with small veins of granular epidote are present in the clear zones. At their margin they are replaced by amphibole aggregates in small undeformed grains showing idiotopic texture (fig. 4).

Clinopyroxene in stubby prisms with straight or slightly curved boundaries. Clear cleavage traces with reddish coating. Colorless and apleocroic; $Z^\frown c = 38°\text{-}40°$.

Garnet is present in the core (a), as well as in the wall zone (b): a) faintly colored in pink, in small cloudy grains intergrown with epidote; b) small idioblastic grains very clear but often marginally chloritized (fig. 5).

Biotite is present only in the wall zone in isolated underformed lamellae. Very faint pleocroism.

Sericite aggregates are very widespread especially in the wall zone; they are interpreted as products of sericitization (Verglimmerung) of plagioclase by BÄCHLIN (1937). In the second specimen it is possible to recognize relics of the original plagioclase.

Titanite: large idioblasts are widespread in every zone. Often showing intense post-crystalline deformation. *Apatite* is very widespread in tiny idiomorphic crystals. Spots or streaks of opaque minerals are scattered through

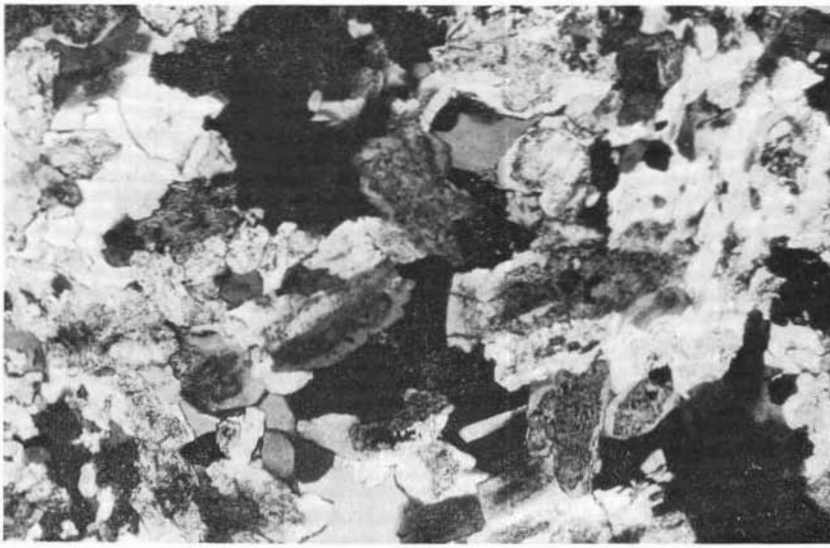

Fig. 3. — Zoned epidote in the central part of the 2nd specimen. Crossed nicols 100 ×.

Fig. 4. — Deformed 1st generation amphibole (right) replaced by an aggregate of underformed 2nd generation amphibole showing idiotopic texture. Crossed nicols 60 ×.

the whole xenolith while graphite is mostly concentrated in the peripheral zone. *Chlorite*, pseudomorphous on biotite, is rather widespread in the wall-zones of the second specimen.

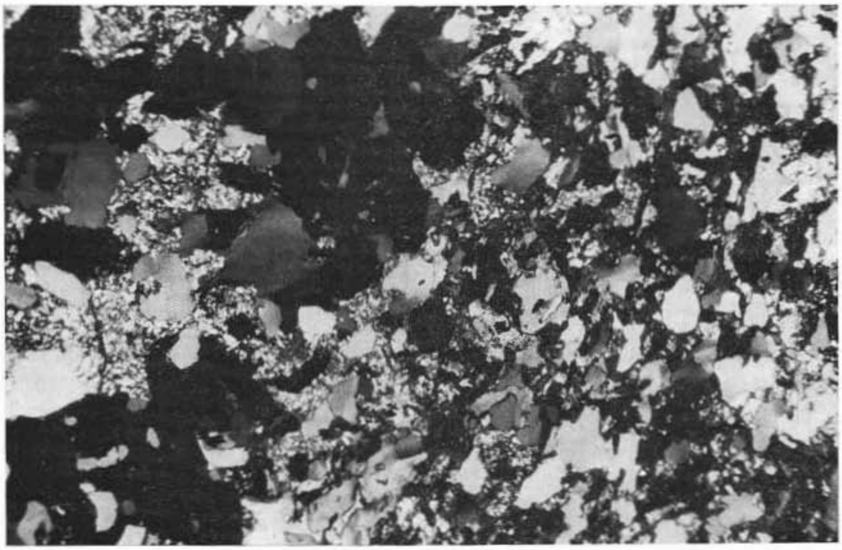

Fig. 5. — Quartz-garnet nodule (left) in the wall zone of the 2nd specimen; note the sericite aggregates replacing an original plagioclase. Crossed nicols 60 ×.

Literature.

ESKOLA (1922) studied carbonate rocks enclosed within a granitic gneiss, considered an ortogneiss, and attributed the formation of calc-silicates in the carbonate rocks and those nearby to the reaction between the magma and the xenolith, and used the mineral assemblage as geothermometer to evaluate the temperature reached during the mineral formation.

BÄCHLIN (1937) in his survey on the Sottoceneri rocks, carefully described both the xenoliths of the « Cenerigneisses » and those of paragneisses; the mineralogical assemblage is given in the following scheme:

surrounding rock:		mineral assemblage: quartz, oligoclase, biotite
reaction zone with biotite	zone 1	mineral assemblage: quartz, andesine, biotite
	zone 2	mineral assemblage: quartz, labradorite, garnet
	zone 3	mineral assemblage: quartz, bytownite, biotite
reaction zone with hornblende	zone 4	mineral assemblage: quartz, anortite, dark hornblende
	zone 5	mineral assemblage: quartz, dark hornblende clinozoisite
	zone 6	mineral assemblage: quartz, zoisite, clear hornblende
nucleo	zone 7	mineral assemblage: quartz, zoisite, diopside, hornblende, calcite.

The xenoliths of the paragneiss are interpreted as concretionary carbonate nodules in the original clayely sediment. Normally the reaction which take place between the enclosing rock and the xenolith is not considered necessary as an explanation of the formation of the successive shells; assemblages observed in the different shells of « Cenerigneisses » xenoliths seem very similar to those originated by contact metamorphism described by TILLEY (1925). Their present position and shape was originated by a late phase of deformation, which determined the breakage of the original xenolith into smaller fragments; the individual fragments may be still in continuity or completely isolated in the gneiss mass.

HENTSCHEL (1943) described calc-silicate xenoliths in migmatic rocks from Eulegebirge: the assemblage in the successive shells is the following:

core with quartz, hessonite, clinozoisite, zoisite, pyroxene, calcite and accessories;

aureole: *a*) pyroxene zone with quartz, pyroxene, anortite, zoisite, clinozoisite, chlorite

b) hornblende zone with quartz, hornblende, labradorite

c) transition zone to the gneiss with quartz, oligoclase, almandine, biotite.

The reaction shells prevented the complete assimilation of the xenolith which could proceed only in the case of a strong internal deformation. The whole transition zone fills the chemical gap between the xenolith and the enclosing rock.

HÄRME & LAITALA (1955) studied basic xenoliths from the Snappertuna region by means of detailed chemical analyses. The authors demonstrated that during migmatization Ca and Na migrated from xenoliths towards the rock, while K and Fe increased in the xenoliths; therefore the presence of a reaction rim of constant thickness surrounding the xenoliths demonstrates the existence of a metasomatic process.

CALLEGARI & MONESE (1961), in a survey on the ultrabasic lenses enclosed in the San Fedelino granite, demonstrated by means of chemical analyses that the zoning of xenoliths is due to a contact metamorphism accompanied by metasomatism between the granitic magma and the ultrabasites at high temperature and in the presence of a vapour phase. Furthermore, the physico-chemical conditions were the same all over the xenolith; therefore the different assemblages can be attributed to the capacity of the various ions to migrate.

MENHERT (1968), in his book on migmatites, emphasized that although the calc-silicate xenoliths in migmatites show zones with assemblages imputable to different grades of thermal metamorphism, xenoliths must be attributed to a single facies because the P T conditions were the same in the whole environment.

Conclusions.

From the study of the xenoliths of « Cenerigneiss » it is possible to add something to the knowledge of the origin of this rock.

The xenoliths represent thin carbonate or marly levels intercalated into an arenaceus series (flysch); it is possible that the present core chemically represent this previous material, while the reaction zone is the geochemical transition to the enclosing migmatite (HENTSCHEL 1943, ALLAART 1958).

Therefore the zoning of xenoliths does not represent any original difference in composition, but it is due to an ion exchange occurred during a phase of intense mobilization. Mainly SiO_2 moved into the original carbonate rock, while CO_2, probably accompanied by Ca, left the xenolith and was partially reduced to graphite along the margin.

This is in accordance with the views of many authors on the origin of zoning in the xenoliths in migmatite gneisses (HENTSCHEL 1943, HÄRME & LAITALA 1955, CALLEGARI & MONESE 1961).

The present external and internal shape of the xenoliths is highly complicated; in fact on the outcrop surface there are very apparent interruptions, thicknings or thinnings of the different shells on one or both sides of the xenoliths. If zoning is due to metasomatism, the thickness of the concentric various shells might be constant, occurring at the same P T conditions all over the xenolith. Therefore the present separation between xenolith and enclosing rock, as well as the boundaries between the different shells, cannot be primary but must be due to a later deformation that changed the original relations.

The existence of such deformation is confirmed by the microstructure observed in the more deformed of the two specimens investigated.

The mesoscopic and microscopic observations permit the following evolution scheme to be drawn:

a) anatexis of the ground rock, but not of the carbonate-rich intercalations; metasomatic exchange between xenoliths and the surrounding melt with formation of concentric shells of nearly constant thickness (HÄRME & LAITALA 1955). Possible syn-anatectic rotation of some xenoliths (ALLAART 1958). Crystallization of the migmatite with unknown texture;

b) strong deformation that led to the separation into several fragments of each xenolith and reduction, and perhaps removal, of the individual shells which resulted in a formation of new incomplete xenoliths;

c) static phase which determined the recrystallization as idioblastic aggregates of undeformed crystals of the large amphiboles present in the more deformed xenolith.

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