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METALLOGENIC STUDIES OF PB-ZN-BA OCCURRENCES IN THE LOWER AND MIDDLE PALEOZOIC SEDIMENTARY ROCKS OF THE LOWER ST-LAWRENCE AND NORTHERN GASPESIE AREA, QUEBEC

PART I

by

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RÉSUMÉ

Le présent rapport concerne 10 des 23 indices minéralisés du Bas Saint-Laurent et de la Gaspésie septentrionale que nous avons cartographiés, échantillonnés et étudiés durant l'été 1984. Une description de terrain pour chacun des indices est accompagnée d'analyses pétrographiques tant en lumière réfléchie que transmise.

Les sulfures prédominants sont de la galène et/ou de la sphalérite, liés aux remplissages de diaclases, de failles, de fractures irrégulières et, exceptionnellement, de réseaux de cavités tardives de la séquence sédimentaire paléozoïque. Les minéraux de gangue les plus importants sont de la barytine dans deux indices, le quartz dans deux autres et des carbonates (principalement de la calcite) dans le restant.

Ensemble, le minérai et les minéraux de gangue forment des filons d'épaisseur variant de quelques millimètres à plusieurs mètres, dont surtout les plus importants ont des directions et des pendages bien définis. Toutefois, trois de ces indices filoniens sont accompagnés de galène disséminée dans l'encaissant.

Malgré la grande diversité des filons, l'étude montre que tous ont été formés postérieurement aux dernières manifestations de la tectonique cassante de l'encaissant.

Fréquemment les filons bien définis sont caractérisés par une distribution préférentielle des sulfures près des salbandes, en particulier dans les cas où les minéraux de gangue ont une texture de croissance orientée à partir des épontes vers l'intérieur du filon ("comb-texture"). La galène disséminée dans l'encaissant, mentionnée ci-dessus, se trouve elle aussi à proximité des épontes.

Les relations temporelles de la précipitation de la galène et de la sphalérite ne sont pas systématiques: dans plusieurs filons la galène était formée après la sphalérite, dans d'autres avant celle-ci.

La sphalérite ne montre pas de zonage, sa couleur variant quasi aléatoirement de verdâtre à jaunâtre et brunâtre. Ceci est interprété comme une indication d'un événement unique, de courte durée, de la déposition des sulfures dans les filons ou le filon d'une indice.

ABSTRACT

Galena and/or sphalerite are the dominant sulfides in ten essentially vein-, fracture- and vug-bound mineral occurrences in the Paleozoic sedimentary sequence of the Lower St-Lawrence and northern Gaspésie area. Dominant gangue minerals are barite in two occurrences, quartz in two others, and carbonates (mainly calcite) in the remainder. Three are accompanied by traces of disseminated galena.

Field study and microscopy of these diverse occurrences show that they are post kinematic with respect to the latest brittle-deformation history of their diverse host rocks.

Well defined veins are commonly characterized by a preferred distribution of their sulfide load near the selvedges, especially so where the gangue minerals show a comb-textured pattern of growth.

Galena-sphalerite inclusion-enclosure relations show no generally valid paragenetic sequence of these two minerals. The absence of zoning in sphalerite is inferred to be evidence for a unique and short-lived event of sulfide-mineralization in the filling of the vein(s) constituting an occurrence.

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MAP (1:500 000)

Localisation des indices de minéralisation en Pb-Zn-Ba dans les roches sédimentaires du Paléozoïque inférieur et moyen - Bas Saint-Laurent et Gaspésie septentrionale.

INTRODUCTION

The Part I of this report is concerned mainly with the petrography of ten of the twenty three mineral occurrences studied and sampled by a field party of INRS-Géoressources in the summer of 1984, under contract with the Government of Canada[1].

Based solely on the results of the field work, Table 1 shows that it is possible to subdivide the twenty three occurrences into three types of vein-bound mineralization according to the dominant species of gangue mineral, whereas a fourth, disseminated, type is not accompanied by any gangue mineral visible to the naked eye. Table 1 shows, in addition, tentative correlations of the four categories so defined with stratigraphic age and/or lithology of the host rock, as well as with sulfide assemblages.

Most occurrences being vein-bound, it was decided to select for the present first phase of the petrographic work several representatives of each of the three categories of veins. Criteria guiding this selection were (1) the maximum number of contacting sulfide species; (2) the presence of both vein-bound and seemingly disseminated sulfides in

[1]Originally entitled "Études métallogéniques des filons minéralisés en plomb-zinc-barytine dans les roches du Paléozoïque inférieur de la Gaspésie septentrionale" (contrat no OST 84-00005), the study is in reality not confined to Gaspésie and several mineral occurrences are not vein-bound (see map).

the same occurrence; and (3) firm knowledge of the orientation(s) of the vein(s).

Thus having chosen the ten occurrences described in Part I of this report, all available samples of each were inspected and the "best" selected for the preparation of thin sections[2]. Table 2 shows, among others, the numbering system of the sections studied; for instance 21N/13-6-A-2 stands for the second section of sample A from occurrence 21N/13-6.

In the text we shall briefly describe the gross habit of a given occurrence, commonly illustrated by a printable field sketch; this will be followed by the petrography, while repeating as little as possible the documentation contained in plates and legends of photomicrographs, as well as that in Table 3.

[2]The selected hand specimens were slabbed; the slabs inspected; the "best" areas of the slabs cut out for the preparation of doubly polished thin sections. Care was taken, in the mounting of the blocks cut out, not to exceed a temperature of 50°C. Most sections are thus accompanied by a "witness" block, about ½ cm thick, covering the same area as the section.

OCCURRENCE 21N/13-6

Excellent exposure of this occurrence is provided by a 300 x 10 m road cut on the east side of highway 20 (Fig. 1). A well-bedded sequence of sandstone, siltstone, conglomerate and subordinate shale is cut by numerous, generally normal faults and several sets of quartz-calcite-filled fractures. Displacement of bedding and fractures along these faults ranges from several centimeters to several meters. None of the generally steeply dipping barite veins has been observed to participate in these displacements and at last one vein forms the apparently undisturbed filling of a fault. This, and the fact that no quartz - and/or calcite-filled fractures cut across the barite veins (Fig. 2), demonstrate that the veining event was the latest in the local structural evolution.

Well-defined barite veins, all but one being restricted to the sandstone-siltstone sequence, range from 1 cm to 1 m in thickness and have an average orientation of 157/77° SW (24 measurements; G. Beaudoin, pers. communication, March 1985). The one exception is the fault-bound vein, traversing both the sandstone-siltstone sequence and an interval dominated by shale. In addition, stock works of barite veinlets occur locally and may connect major veins.

Barite, apparently restricted to veins and veinlets, occurs throughout in coarse- to medium-sized acicular to rhombic crystals without preferred form-orientation. Galena and sphalerite, in coarse- to medium-size euhedral crystals are present in - and are restricted to - the veins, without preference for rim or center; they are rarely mutually closely associated and grain-to-grain contacts are extremely rare (see also Table 3).

Microscopy

Remarkable features (Plate I) are (1) the presence of perfectly euhedral quartz grains in the barite veins and (2) the overgrowths of quartz on detrital quartz grains where the sandstone is in contact with the barite vein. The latter feature is not restricted to the veins; it has been observed as well along barren quartz-calcite fracture fillings. This suggests that the deposition of gangue quartz constituted the first stage of fracture filling and is not causally related to the subsequent filling of the vein. The euhedral quartz grains occurring in the barite matrix are thus interpreted as crystals removed from the walls of the veins by subsequent circulation of the fluids that participated in the precipitation of the remainder of the vein filling.

Plate II illustrates inclusion - enclosure relations of galena, sphalerite and barite pointing, at least locally, to early precipitation of galena with respect to sphalerite and barite. In general, the mutual temporal relations of sphalerite and barite are not clear: protrusions and inclusions of the one in the other are common.

No zoning is evident in the sphalerite; ill-defined patches and flecks of canary-yellow are randomly distributed in colorless to light yellow crystals.

While the euhedral shape of the major sulfides is conspicuous in the field, ragged grain boundaries, in particular of galena, are not uncommon under the microscope (cf. Plate IA). Tiny stringers of such ragged galena grains, located near a vein-host contact, do occasionally penetrate into the matrix of the sandstone (cf. Plate IB).

OCCURRENCE 22C/7-4

Located on the southeastern side of a steep hill, this occurrence is subdivided into two major exposures: (1) one is constituted by part of the steep flank of the hill and an addit at its base; (2) the other, about 500 m south-southwesterly from the former, is a wide, formerly quarried, gully in the flank.

The host rock is a coarse polymictic conglomerate with about 60% poorly sorted, subangular to subrounded pebbles and boulders of various types of limestone, set in a sandy calcite matrix. At exposure (1), this conglomerate is underlain by a fine-grained sandstone, at least 10 m thick.

Exposure 1 consists mainly of underground workings (Fig. 3) that show a set of 5-cm wide barite veins rich in medium to very coarse galena cubes and a 1.5-m wide barite vein poor in galena. The barite in the veins consists of coarse to very coarse prisms with a marked comb structure, especially so in the central parts of the veins. The veins are characterized by up to 50%, apparently barite-supported, rotated, small and large (up to 30 cm) angular enclaves of the host rock and a cherty rock (Fig. 4). Calcite-filled fractures without marked preferred orientation are abundant; they do not appear to cut across the barite veins.

The muck-pile outside the addit contains numerous hand-specimen sized fragments of sandstone with disseminated galena, vaguely resembling the much finer-grained and siliceous sandstone underlying the calcareous conglomerate.

Exposure 2 shows an anastomosing, very coarsely crystalline barite vein, 0.5 to 1 m wide (Fig. 5). A few grains, up to 1 mm in diameter, of galena, chalcopyrite and sphalerite are present (note that no sphalerite was seen in Exposure 1).

Henri (1984), reporting on an area of 40 km^2 stretching from the St-Lawrence River southeastward, shows ten barite occurrences, including the present 22C/7-4 as well as our 22C/7-3 (a dedicated search for the seven-odd remaining showings was unsuccessful). Synoptic stereonet plots in Henri's report of faults (78), joints (357) and barite veins

(63) show gross parallelism of these three planar elements. The attitudes of the veins are less constant: most strike NW-SE to N-S, dipping steeply to the SW or NE and to the West respectively.

Microscopy

A section of a highly porous specimen of barite, rich in "cherty" enclaves shows that the enclaves consist of aggregates of semi-mylonitic quartz set in a well-crystallized, undeformed host of barite (Plate ID). Apparently, deformation of these types of enclaves preceded enclosure in barite. The absence of quartz overgrowths suggests that the strained quartz lattice did not allow development of an incipient euhedral outline (cf. occurrence 21N/13-6).

Unsuspected from the field observations, galena occurs not only in the barite veins but also, in the form of fine (<1 mm) subhedral to euhedral crystals, contiguous to these veins as well as in and contiguous to some highly irregular veinlets of polygonal to comb-textured calcite (see also Table 3).

OCCURRENCE 22C/7-5

Located about 500 m southeast of a microwave tower, the occurrence consists of a debris-filled, overgrown 3-m long trench and adjoining pit. The pit, once 11,4 m deep according to the "Fiche de gîte minéral" is caved in and filled with stumps of trees and garbage, leaving a 2,5-m wide, 0,5-m deep hole. On one ledge of this hole, the actual showing is fairly well exposed (Fig. 6).

The host rock is similar to the polymictic calcareous conglomerate of occurrence 22C/7-4 but contains some large angular blocks of sandstone. Several faults, all striking NW-SE and dipping steeply to the east traverse the showing; one of these forms the contact between the host rock and adjoining sandstone. Three well-defined veins, consisting of massive galena with or without subordinate calcite, are present; 0,5 cm to several centimeters thick, they are parallel to the faults. In general, galena does not seem to be preferentially associated with calcite veins, veinlets and patches that occur abundantly in the host rock as mutually intersecting, highly irregular networks.

Next to this mode of occurrence, galena is sparsely disseminated in cubes, 1 to 2 mm in diameter, in the conglomerate at distances of up to 15 cm from the coarse-grained, vein-bound galena. The abundance of calcite veinlets and patches, especially clearly visible on cut faces of large specimens, makes it virtually impossible to state with confidence that the disseminated galena occurs only in the matrix of the conglomerate, or within its clasts as well.

Microscopy, X-ray diffractometry

Having noticed in the field the presence of gypsum in a calcite veinlet, a number of such veinlets and calcitic patches were separated by means of a Dremmel moto-tool from several slabbed specimens. X-ray diffraction of the resulting powders (5) failed to show the presence of sulfates - calcite, minor quartz, traces of dolomite and barite were identified instead.

A section across the major galena vein of figure 6 shown a curious type of zoning; over a distance of 16 mm at right angles to the vein, three zones occur: (1) coarse, crystalline, massive galena, locally with strongly bent cleavages; (2) an interconnected network of galena stringers and subhedral galena crystals dispersed in the wall rock; and (3) a more and more sparse distribution of galena in diffuse, isolated stringers and finally galena seemingly disseminated in the host rock. Remarkable is the fact that no genuine gangue mineral is evident; the mineral in contact with galena is predominantly quartz in the various forms and of the size-range of the common host-rock quartz.

Microscopy has substantiated and amplified the field observation of the presence of disseminated galena remote from the major vein-bound variety. It occurs (1) in anastomosing, discontinuous calcite-quartz veinlets; (2) truly disseminated in fine, anhedral, highly irregular grains within some, mostly quite quartz-rich, clasts; as well as (3) in the perfectly euhedral form illustrated in plate IIIC.

The at least four modes of occurrence of galena described above tend to suggest one or more episodes of remobilization and reprecipitation; insufficient evidence is available, however, to establish relative ages on the basis of this showing alone.

Finally, Plate III (A and B) shows the inclusion - enclosure relations of galena and the quite rare sphalerite; the opposite relation (galena inclusions in sphalerite) has not been observed, although a few major sphalerite crystals are present.

OCCURRENCE 22B/12-13

Former exploration work around the occurrence has left two barren trenches in the longest of which (50 m) barren fine-grained calcareous sandstone is well exposed. In addition, a water filled pit is present, 6 m in diameter and 2 m deep. Bedrock in the pit is a small, poor exposure near the water table, but piles of blasted blocks surround it. All mineralized samples collected are from this rubble.

The host rock is a breccia consisting of about 60% non-sorted, subrounded to angular fragments of grey, fine-grained, highly calcareous sandstone set in a white, medium-grained matrix of quartz, calcite and sphalerite. The matrix forms an irregular network with numerous pores, partly filled with anhedral calcite, and euhedral quartz and sphalerite. Some clasts of blackish shale fragments are present as well; sulfides (sphalerite, pyrite, chalcopyrite; see also Table 3) tend to be concentrated in ill-defined zones, up to 5 cm wide, contiguous to the contacts of shale and matrix.

The mineralization is clearly breccia-bound, more particularly matrix-bound; no major mineralized (or barren) veins have been observed.

Microscopy

Plate IV (A, B, C) demonstrates the paragenesis of the vug-filling minerals: euhedral quartz prisms formed an early coating of the vugs, while the remaining space was entirely or partially filled by calcite with or without sphalerite (see also legends to Plate).

The sphalerite occurs in euhedral to semi-euhedral crystals up to 2 mm in diameter; it is colorless, light greenish, various shades of yellow to reddish brown. These colors may occur in the same crystal, the darkest commonly near the center. The crystals are, however, never clearly zoned.

Although chalcopyrite and pyrite are rare, grain-to-grain contacts of all three pairs of sulfide species have been observed. Plate IV D suggests that chalcopyrite and rare bornite are the latest sulfides to be precipitated.

OCCURRENCE 22B/14-2

Three pits, a trench and two adits are witnesses of previous exploration activity in the outcrop-rich hills surrounding the occurrence. Sulfide mineralization has only been observed in one of the pits, 2,5 m in diameter and 2 m deep.

The host rock is a polymictic conglomerate with 80% ill-sorted, subrounded to well rounded clasts ranging from 0,1 to 40 cm in diameter. Various types of limestone, calcareous sandstone, quartzite and calcareous shale are set in a matrix of quartz sand, cemented by calcite.

Sparse sulfides (Table 3), other than sizeable rounded clasts of pyrite, are restricted to irregular networks of calcite veinlets, 0,1 to

3 cm wide, without obvious joint or fracture control. The veinlets are hard to distinguish from the matrix of the host rock, although they locally cut across some clasts. Major mineralized or barren veins are absent.

Microscopy

The only gangue mineral present within and partially surrounding stringers of sulfides is calcite. Gangue quartz is definitely absent.

The sulfides occur in fine- to medium-sized grains; galena and pyrite may be euhedral, subhedral and anhedral, while chalcopyrite is invariably anhedral, with covellite restricted to its rims.

Galena contains inclusions of pyrite, cements neighboring pyrite crystals and interpenetrates pyrite grains by means of vein-like offshoots, all pointing to late precipitation of galena with respect to pyrite. Chalcopyrite inclusions in galena are rare, but do occur. Judging by inclusion-enclosure relations, chalcopyrite precipitated, as did galena, later than pyrite. The most likely paragenesis is thus, from early to late: pyrite-chalcopyrite-galena.

OCCURRENCE 22A/9-2

The number 22A/9-2 comprises two separate occurrences, indicated in this report as 22A/9-2(1) and (2). The first, most southerly, showing is probably the one described in the "Fiche de gîte minéral"; it occurs in the steep wall of a narrow valley of a brook (Fig. 7). Downstream, at a distance of about 140 m due north, the second showing occurs in an erosional hole at the southern margin of Gravelly Brook, close to the summertime water-level. Five-odd trenches along the narrow valley and a small stockpile of galena near occurrence 1 testify to previous mineral exploration in this area.

<u>Occurrence 22A/9-2(1)</u>. The most rock is a well-bedded homogeneous, cherty calcilutite. A set of joints and two well defined mineralized veins strike N-S and dip 65 to 70°W. A third vein strikes NNE and dips 87°E, while slabs of galena adhering to the wall are erosional remnants of a fourth, irregular, vein striking about E-W and dipping 65°S. Some minor irregular veinlets and pockets nearby contain only pyrite or marcasite and coarse gangue carbonate.

The veins, up to 3 cm wide, contain mostly pure galena in coarse cubes, generally separated from the vein wall by a thin rim of white carbonate. Large masses of sparry calcite occur in the rubble in a trench contiguous to the showing but have little or no sulfides. The best sample, collected in the streambed from the left-hand vein in figure 7, contains several sulfides, abundant "rust" as well as spar in an asymmetric zoned arrangement.

Occurrence 22A/9-2(2). Extremely poorly exposed, this showing is probably hosted in the same sequence of calcilutites. Fragments and one exceptionally good sample, containing an entire 4 cm wide vein, show a macroscopic zoning similar in some respects to the sample of occurrence 1 mentioned above. It does, however, not contain any galena.

Microscopy, etc.

Occurrence 22A/9-2(1). The zoning in the specimen referred to above is as follows: (1) the immediate host rock is a very-fine grained to cryptocrystalline, altered quartzofeldspathic rock; it contains numerous disseminated marcasite crystals; (2) a 2-mm wide zone of massive gangue-carbonate containing fine marcasite crystals; (3) an even thinner, highly discontinuous zone of euhedral marcasite partially separating the gangue from the next zone (Plate VA); (4) a zone of coarse-grained galena, with marcasite inclusions only on the contact with the previous zone; (5) a zone of brownish yellow to dark brownish sphalerite, containing stringers of partially oxidized marcasite (Plate VB); (6) a zone of massive, bladed marcasite, slightly to highly altered into iron-oxyhydroxides (Plate VC). Despite the zoning, all minerals, gangue and sulfides, are locally in grain-to-grain contacts.

X-ray diffraction shows subequal amounts of calcite and dolomite or ankerite as the only gangue minerals. In thin section, these species are indistinguishable. Sphalerite, although patchily varying in color, does not show any well-defined zones.

The galena inclusion in sphalerite of Plate VD, observed once, is the only evidence for a possible paragenetic relation between these two sulfides.

Occurrence 22A/9-2(2). Essentially similar in zoning to the previously described vein, outstanding differences are: (1) fine, disseminated, lozenge-shaped carbonates (probably ankerite; "dol" in Table 3, under "Disseminated"), pyrite spherules and marcasite crystals dominate the immediate host rock; (2) the zones of carbonate gangue and iron-sulfides contain both pyrite and marcasite crystals; (3) galena is absent; (4) dark orange-brown sphalerite, tightly intergrown with coarsely crystalline marcasite and pyrite is followed along a knife-sharp contact by a zone of light greenish-yellow sphalerite. Again, all minerals, gangue and sulfides, are locally in grain-to-grain contacts.

OCCURRENCE 22A/16-4

Formerly (1665) exploited, the occurrence is located on the camping grounds at the northern end of Forillon Peninsula. Main exploitation (20 tons of 60% Pb) was from a presently boarded-over pit, 6 meters deep, according to the "Fiche de gîte minéral". The main showing at present is a 12x2x2 m trench, dug along the strike of a white calcite-galena vein (orientation 355/70°E) of which slabs cling to the grey, well-bedded and laminated, cherty limestone host. The remainder of the vein is preserved at the northern end of the trench (Fig. 8).

The vein displays a marked symmetric growth-zoning: a medium- to fine-grained, massive calcite rim on either side of the vein is followed inward by coarse- to very coarse-grained calcite crystals elongated perpendicular to the vein walls. In the center of the vein, the terminations of these crystals, grown from either side of the vein, barely touch each other or leave an open space ("p" in Table 3; Fig. 9).

Galena cubes, 2 to 15 mm in diameter, similarly sized angular enclaves of host rock and rare fine-grained chalcopyrite and pyrite occur exclusively in the vein rim (Fig. 9).

Microscopy

Galena - and its replacing substances - are closely associated with, but not entirely confined to, the calcite vein. Plate VIA shows partial replacement of a euhedral galena crystal by semi-metallic aggregate (Pb oxide or hydroxide), minor iron-oxyhydroxide, and traces of covellite and chalcopyrite; the crystal is located in limestone, contiguous to gangue calcite of the vein. Plate VIIA shows a similar replacement, but here entirely consisting of the semi-metallic substance referred to above. This replacement is not exceptional and explains the presence of numerous microscopic, anhedral grains of galena scattered throughout the rim of the vein.

Quite unexpected from the field observations is the partial to complete replacement of galena by chalcopyrite (Plate VIA to D). The latter mineral, in its turn, is patchily to marginally altered into iron-oxyhydroxides and, more rarely, covellite.

The occurrence of rare euhedral inclusions of pyrite in chalcopyrite suggest late precipitation of chalcopyrite with respect to both, pyrite and galena.

OCCURRENCE 22A/16-6

The occurrence and its surroundings are well-exposed at the base of the cliffs along the western shore line of Forillon Peninsula. The host rock is a hard, well-bedded, highly fossiliferous limestone, broken up by a well-developed set of joints (275°/80N) and traversed by numerous, mutually parallel, spar-filled tension cracks.

Two sets of these cracks line up and give rise to two fairly well defined, subvertical veins, striking N-S and up to 5 cm wide (Fig. 10). Locally displaying a well-developed comb structure, they are filled with pinkish calcite, some dolomite, a little quartz and sparse cubes of galena, 1 to 4 mm in diameter. The sulfide is not restricted to relatively wide parts of the vein; it may form druzy coatings of very fine galena crystals in 0,5 mm wide sections of "the" vein. Galena is present as well disseminated in the limestone in fine, discontinuous, ill-defined stringers and in isolated specks, up to several centimeters from the main vein-hosted occurrence.

Sixty meters west of the main showing, numerous similarly oriented and spar-filled tension cracks are present, a single one of which contains a pod of sphalerite, 0,5 cm in diameter. No galena is present here.

Microscopy

Plate VIII substantiates and amplifies the above field description, whereas Plate IX (from the same hand specimen) shows that the "isolated specks" of galena in limestone are curiously associated with birdseyes, apparently replacing the rims of these spar-filled fenestral textures.

It is noted that the enclosure of the spar-rhomb in galena (Plate VIIIB) substantiates the above inference of the formation of spar previous to the precipitation of galena to the extent that sparitization did take place only once.

OCCURRENCE 22H/4-1

Spectacular mineralization in rubble blasted from a trench, several cubic meters large, and fairly well exposed bedrock occur in a heavily wooded, hilly area on the valley wall of a small stream.

The host rock is a dark grey, silty, carbonate-bearing shale with a well-developed cleavage (254/45°N) subparallel to an ill-defined bedding. A set of joints, spaced 20 to 50 cm apart, and five well-defined veins strike NW-SE and dip from 45° to 64° SW (Fig. 11).

The veins, 3 to 20 cm wide, are filled with prisms of quartz up to 6 cm long, aligned perpendicular to the vein-walls. Pointing from both walls inward, they leave an open space in the center of the vein, along which coarse to very coarse euhedral pyrite crystals adhere to the quartz. Coarse blebs, up to 5 cm in diameter, of sphalerite, galena, pyrite and a highly weathered, powdery, rusty-red material occur mainly along the margins of the veins and, in minor concentrations, in aggregates aligned perpendicular to the vein walls (Fig. 12). Rarely occurring in identifiable form, the rusty red material accounts for about 5 to 10% of the vein; it appears to be a carbonate, probably dolomite or ankerite with minor calcite. In addition to the major open, pyrite-bearing space in the centers of the veins, pores up to several millimeters in diameter are present between the coarse prisms of quartz. Occasionally partially filled by small prisms of quartz, with or without euhedral crystals of sulfides, it is quite possible that the minor concentrations of sulfides and carbonate referred to above did, in fact, occlude such a porosity.

Microscopy

Although the constituents of the veins are too coarse-grained to be fully contained in photomicrographs, the set of plates X to XIII shows relatively large fields of view and the potentially most significant details from samples of the three veins shown in the upper part of figure 11, including the sample sketched in figure 12. These four plates and their legends should suffice to document the intricate textural relationships of the galena-sphalerite-carbonate aggregates set in a matrix of quartz near the margins of the veins.

Without taking recourse to the hypothesis of extensive replacement of carbonates by sulfides, or vice versa, it is suggested that the simplest explanation for the gross relations is precipitation of sulfides subsequent to that of gangue carbonates - combined perhaps with some readjustment of the distribution of elements in the carbonate lattice (note the remarkable zoning, "molding" as it were, aggregates of sulfide). Depending on the presently ill-known paragenetic relations of gangue quartz (several generations ?) and carbonate, a possible contradiction to the above hypothesis is the presence of some small (40-400 μm) grains of galena in a major crystal of gangue quartz.

These grains are not related to any heterogeneity, crack or fissure in the quartz.

Sphalerite varies in color from light yellow to light orange-brown but no zoning is evident. The mineral is commonly criss-crossed by channels containing a brownish, poorly translucent substance, possibly a feature of surficial alteration. The occurrence of chalcopyrite is mostly confined to sphalerite, in which it occurs in small grains, veinlets and lamellae without preferred orientation or relation to the cleavage and alteration pattern of the host mineral.

Carbonate, the zoned gangue mineral, commonly has an irregular gliding extinction, strongly reminiscent of "saddle dolomite" (Radke and Mathis, 1980).

OCCURRENCE 22H/4-2

The occurrence is located about 2,5 km north-northeast from the one described above. It is situated on the valley wall and in the streambed near the base of a 200 m high stepped sequence of water falls. The valley wall, 7 m high, is occupied by a trench with a blasted-out rubble pile at its base (Fig. 13).

The host rock is a grey, shaly, carbonate-bearing siltstone, poorly bedded but with a well-developed cleavage (273/30°N). A set of joints, spaced 30 to 50 cm apart, and two major veins strike NW-SE and dip 70° SW. One of the veins is 10 cm wide, the other 4 cm. Two minor veins, from one to several centimeters wide are exposed a few meters upstream from the trench, in the streambed. One cuts across the cleavage and is oriented at right angles to the major veins (245/40° NE); the other is subparallel to the cleavage.

Arrangement of coarse quartz prisms in a comb texture, a discontinuous open space in the center of the vein, the preferred location of sulfide aggregates and the porosity, all are similar to the veins of occurrence 22H/4-1. The following dissimilarities are evident, however: (1) carbonates are much less abundant; (2) no pyrite is present in the central open space; (3) a zoned arrangement, parallel to the walls, of virtually massive sulfides, alternating with virtually barren, porous quartz is conspicuous, particularly in the major left-hand vein of figure 13; (4) a remarkable and possibly significant feature of a sample of the other major vein is that its cuts across, without off-setting, a barren veinlet filled predominantly with rusty-red carbonate.

Microscopy

Excellent fresh samples across the entire vein-widths of the two major veins show an up to several millimeters wide, virtually barren zone of quartz prisms making an angle of 60° to 90° with the carbonate-coated wall of the vein. In this selvedge major "pyramids" of galena and sphalerite are rooted, continuing for several millimeters into the vein, parallel to the quartz prisms. Generally too coarse-grained to be comprised in photomicrographs, Plate XIV (A, B, C) shows several parts of one of these galena growths, whereas Plate XIVD shows an entire sphalerite growth from the opposite side of the same vein (see also legends to this plate).

The sulfide growths, but more particularly the sulfides further into the vein, are moderately to highly poikilitic, containing abundant inclusions and incursions of polygonal quartz. Plate XV shows the remarkable presence of small anhedral to euhedral sphalerite and galena inclusions in these polygonal quartz crystals that are inclusions themselves. Most common are sphalerite inclusions in quartz enclosed in sphalerite and galena inclusions in quartz enclosed in galena. As the major quartz prisms as well as the quartz inclusions contain abundant, sizeable, two-phase (liquid + vapor), primary and secondary fluid inclusions, this occurrence is an ideal one for a detailed fluid-inclusion study.

Sphalerite, as in the previous occurrence, is not zoned and contains numerous chalcopyrite but also some pyrite inclusions. It is not altered. Chalcopyrite is present as well as sizeable anhedral grains not associated with sphalerite (cf. Plate XVIA).

Generally, grain-to-grain contacts of galena and sphalerite are sharp, with minor protruberances of the one in the other. Well defined apophyses of galena in sphalerite, but not vice versa, constitute somewhat ambiguous evidence for relatively late precipitation of the former (cf. Plate XVIB).

CONCLUSIONS AND COMMENTS

1. The clearly vein-bound sulfide occurrences, i.e. at least the major parts of all described in this report except 22B/12-13 and 22B/14-2, appear to be postkinematic, or at best late-kinematic, with respect to the tectonic evolution of their Lower and Middle Paleozoic sedimentary host-rocks. All inhabit planar, non-deformed, fabric elements, parallel to joints, faults and tension gashes. No other barren or mineralized fractures cut across them. Evidence of internal deformation, even of fault-bound veins, is rare and consists mostly of gliding and undulating extinction of some gangue minerals, and bent cleavages of galena. In the case of "saddle dolomite" (22H/4-1) and galena (22H/4-2), such features are most likely due to lattice distortion during crystal growth rather than to an external field of strain.

2. Quartz in the occurrences 22H/4 crystallized during sulfide precipitation; in the others where gangue quartz is present (including 22B/12-13), it appears to form an early coating not related to the precipitation of other vein-and pore-filling minerals.

3. <u>Sphalerite</u> has no color zoning. Despite the various paragenetic relations of this mineral with other vein-filling species, the absence of zoning tends to suggest that a single mineralizing fluid precipitated sphalerite in a short span of time. To the extent that other sulfides formed penecontemporaneously with sphalerite, the mineralization was a unique and short-lived event in the history of a given vein-bound occurrence.

The presence of relatively abundant chalcopyrite "inclusions" in sphalerite, only observed in the occurrences 22H/4, is reminiscent of the so-called "chalcopyrite disease". It is thought to be the result of exsolution (see, however, Craig and Vaughan, 1981, p. 125) and may point to a temperature of precipitation of the sulfide load higher than that of the other sphalerite-bearing occurrences.

4. <u>The preferred distribution of sulfides</u> in and near the selvedges of many veins suggests that reducing micro-environments preferentially developed along the rims of veins, where organic matter in the host rock could act as a reactant and catalyst in the reduction-and-precipitation process. The internal fabric of the vein, in particular the distribution of its paleoporosity, would determine the actual form and distribution of the resulting sulfide aggregates.

5. <u>The disseminated galena</u> in the cluster of barite and calcite veins of the occurrences 22C/7 suggests the presence of several generations of galena. Most striking is the presence of euhedral galena crystals

in sandstone clasts of 22C/7-5 (Plate IIIC). A cursory microscopic study of a galena-rich sandstone sample from the muckpile at 22C/7-4 (Exposure 1) shows that the sulfide occurs mainly as a cement, quite different from the above-mentioned crystals. Clearly, a determined search should be made for galena in the sandstones in this area, notably in the more than 10-m thick sequence of sandstones underlying the conglomerate of occurrence 22C/7-4 (Exposure 1).

6. No conclusions are drawn, at present, concerning the replacement of galena by chalcopyrite (22A/16-4), nor concerning the astonishing disseminated galena replacing birdseye-spar (22A/16-6). For both, more galena-chalcopyrite bearing occurrences and birdseye-rich limestones respectively should be studied (our collection contains three occurrences on Forillon Peninsula not included in this report).

7. In future reports, more drawings or photographs should be included of hand specimens and entire thin sections, preferably stained for vein-bound carbonate species and porosity. This will make such reports more accessible to the reader.

8. A detailed study of fluid inclusions in gangue quartz has been touched upon in the description of 22H/4-2.

9. A study of sulfide-sulfur isotopic fractionation would be useful to the extent that our conclusion of a unique and short-lived event of

sulfide mineralization in the history of the various vein-bound occurrences is valid.

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MINISTÈRE DE L'ÉNERGIE ET DES RESSOURCES DU QUÉBEC, 1983. Fiches de gîte minéral no 22C/7-5, 22A/9-2, 22A/16-4.

RADKE, B.M., MATHIS, R.L., 1980. On the formation and occurrence of saddle dolomite. Journal of Sedimentary Petrology, 50, pp. 1149-1168.

Table 1. Subdivision of Pb-Zn-Ba occurrences in the Lower and Middle Paleozoic sedimentary rocks of the Lower St-Lawrence and northern Gaspésie area.

CATEGORY (SYMBOL[1]) AND NUMBER OF OCCURRENCES		PRINCIPAL CHARACTERISTIC OF CATEGORY: THE DOMINANT GANGUE MINERAL	HOST ROCK	SULFIDE ASSEMBLAGE
x	4	(disseminated)	sandstone - independent of stratigraphic age of host (Cambrian, Silurian, Devonian)	Galena and pyrite invariably present
◆	4	barite	Cambrian and Cambro-Ordovician - independent of lithology of host rock (sandstone, shale, conglomerate)	Galena alone or dominant
●	11	calcite	Limestone or calcite-cemented sandstone independent of stratigraphic age of host (Cambrian, Silurian, Devonian)	Galena (64%) or sphalerite (36%) dominant
▲	6[2]	quartz	Siliceous (sandstone, shale) and Ordovician	Three sulfide species of which pyrite is invariably present with galena and/or sphalerite

[1]Symbol used on appended map

[2]Including Candego and Cromar occurrences

Table 2. Inventory of samples, sections and photomicrographs

1 OCCURRENCE #	2 G	3 COORDINATES (UMG)	4 N	5 n	6 DPT	7 Ph
21N/13-6	ba	5296300N - 457700E	12	A	1	3
				A	2	1
				B	1	5
				C	1	
22C/7-4	ba	5347400N - 508600E	13	D	1	
				I	1	1
22C/7-5	ca	5348850N - 508300E	6	C	1	
				C	2	1
				D	1	2
22B/12-13	ca	5378050N - 589500E	7	B	1	3
				C	1	
				F	1	2
22B/14-2	ca	5420800N - 643800E	5	D	1	2
22A/9-2(1)	ca	5397950N - 391350E	11	C	1	4
22A/9-2(2)	ca	5398050N - 391400E		G	1	
				I	1	2
				I	2	
22A/16-4	ca	5406350N - 408750E	7	B	1	3
				G	1	4
22A/16-6	ca	5403700N - 410800E	6	A	1	2
				A	2	8
				D	1	
22H/4-1	q	5445875N - 295500E	8	B	1	
				B	2(1)	4
				B	2(2)	2
				C	1	
				D	1(1)	8
				D	1(2)	9
				D	2	
				G	1	
22H/4-2	q	5446700N - 297850E	8	C	1	4
				C	2	
				C	3	4
				D	1	7
				D	2	

Column 1: Occurrence # = No. "fiche de gîte" MERQ
Column 2: G = dominant gangue mineral
Column 3: COORDINATES according to Universal Mercator Grid
Column 4: N = total number of samples available
Column 5: n = samples studied (microscopy; minor X-ray diffractometry)
Column 6: DPT = No. of doubly polished thin sections
Column 7: Ph = total number of photomicrographs available

Table 3. Mineral constituents and their relative abundances[1,2,3]

OCCURRENCE #	HOST ROCK	VEIN-BOUND																		DISSEMINATED[4]
		GANGUE MINERALS									METALLIC MINERALS									
		ba	ca	dol	q	mi	pg	i	p		py	ma	gn	sp	cp	bn	cv	i		
21N/13-6	sst	●	x		○				x		x		●	●	x					
22C/7-4	co	●	○						x		○		●	x	x					gn
22C/7-5	co	x	●		○				x		○		●	x	x				arsenopyrite	gn, cp; ba
22B/12-13	sst		●		●				○		x			●	x	x				
22B/14-2	co		●								○		●		○		x			
22A/9-2(1)	Sil 1S		●	○					x			○	●	○				x		ma
22A/9-2(2)	Sil 1S		●	○					○		○	○		●						ma; dol
22A/16-4	ls		●						○		x		●		x		x	x	Pb(hydr)oxide	
22A/16-6	ls		●						x				●	x						gn
22H/4-1	sh		x	○	●			x	○		●		○	○	x			x	x	
22H/4-2	sh			x	●	x	x		○		○		●	●	○					

[1]Based on data from field, specimens and thin sections

[2]See list of abbreviations in Table 4

[3]●: major; ○: minor; x: trace; either gangue or metallic minerals

[4]Exclusive of ubiquitous "sedimentary" pyrite

Table 4A. Abbreviations in tables and plates

alt	alteration product	ma	marcasite
ba	barite	mi	colorless phyllosilicate
bn	bornite	p	open pore space
ca	calcite	pg	plagioclase
co	conglomerate	py	pyrite
cp	chalcopyrite	q	quartz
cv	covellite	sh	shale
dol	dolomite and/or ankerite	sil.	siliceous
gn	galena	sp	sphalerite
i	iron-oxyhydroxide	sst	sandstone
ls	limestone		

Table 4B. Convention for definition of grain size

fine-grained: cryptocrystalline to <1 mm

medium-grained: 1 mm to <5 mm

coarse-grained; 5 mm to <3 cm

very coarse-grained: >3 cm

FIGURE 1 - 21N/13-6

Field sketch of main exposure of occurrence 21N/13-6. Barite veins (solid black) in sandstone sequence of road cut. Several thin barite veinlets are not shown, including the 2-cm thick barite-galena coating along the right most fault plane.

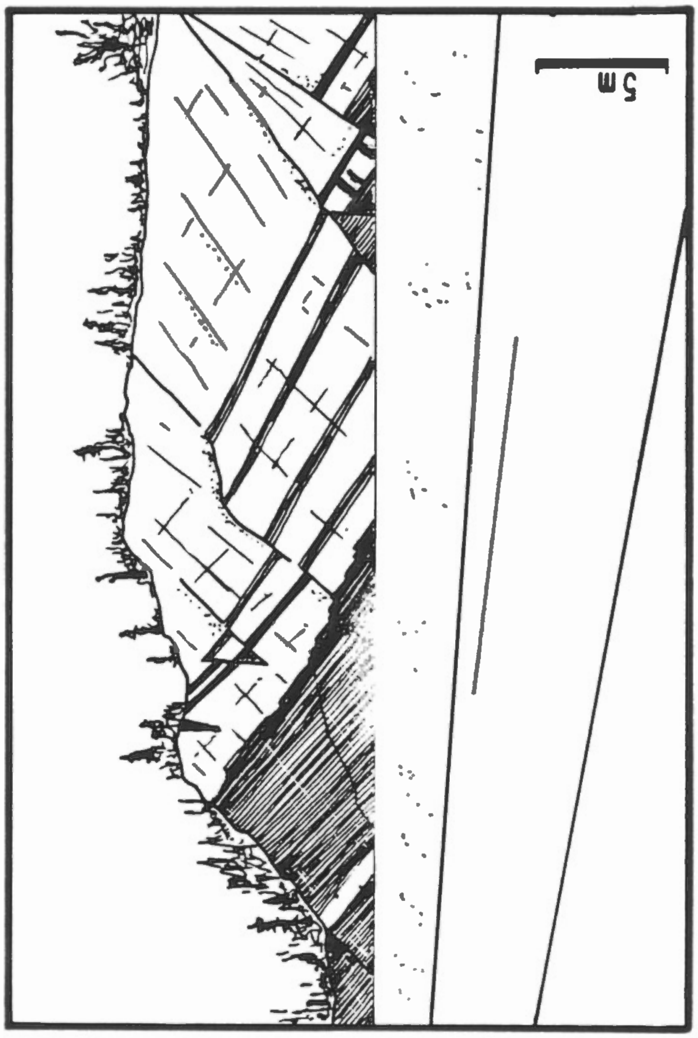


FIG.1-21N/13_6

FIGURE 2 - 21N/13-6

Field sketch of minor exposure of occurrence 21N/13-6, occurring near top of road cut of figure 1. Two well-defined sub-parallel barite-galena-sphalerite veins, connected by a minor barite vein and an associated stock werk of such veinlets.

FIG.2 – 21N/13_6

FIGURE 3 - 22C/7-4

Plan of underground workings of occurrence 22C/7-4, exposure 1. Note abundant inclusions of host rock in major barite vein ("2nd zone").

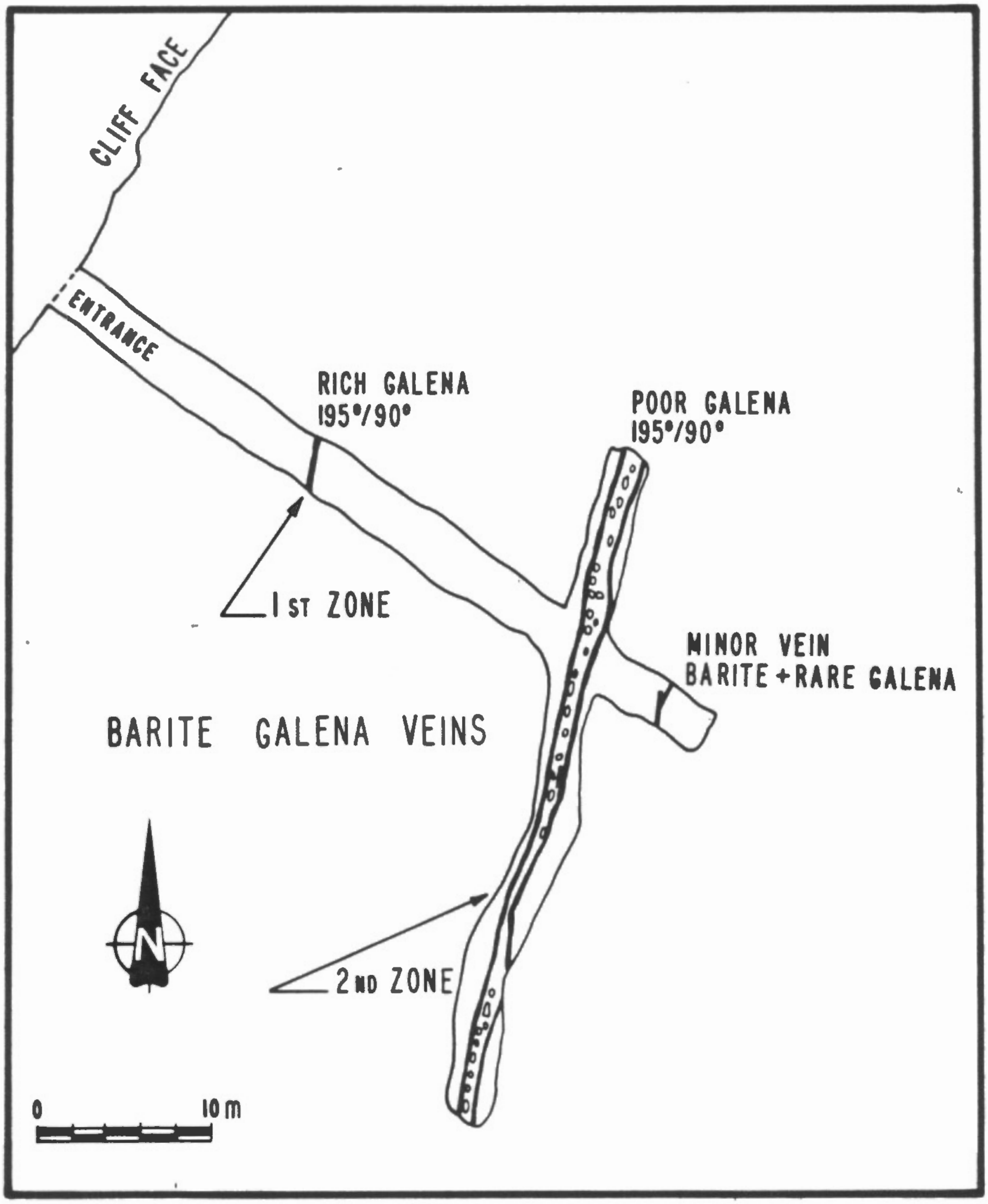

CLIFF FACE
ENTRANCE
RICH GALENA
195°/90°
POOR GALENA
195°/90°
1 ST ZONE
MINOR VEIN
BARITE + RARE GALENA
BARITE GALENA VEINS
N
2 ND ZONE
0
10 m

FIG. 3—22C/7_4

FIGURE 4 - 22C/7-4

Sketch of part of roof in adit of occurrence 22C/7-4, exposure 1. Note coarse comb texture of barite, inclusions of conglomeratic host rock and somewhat exaggerated angular cherty inclusions (dashed).

FIG.4 —22 C/7_4

FIGURE 5 - 22C/7-4

Field sketch of occurrence 22C/7-4, exposure 2. Barite vein forms the left-hand wall of gully, sharply cutting across bedding of calcareous conglomerate at top of exposure.

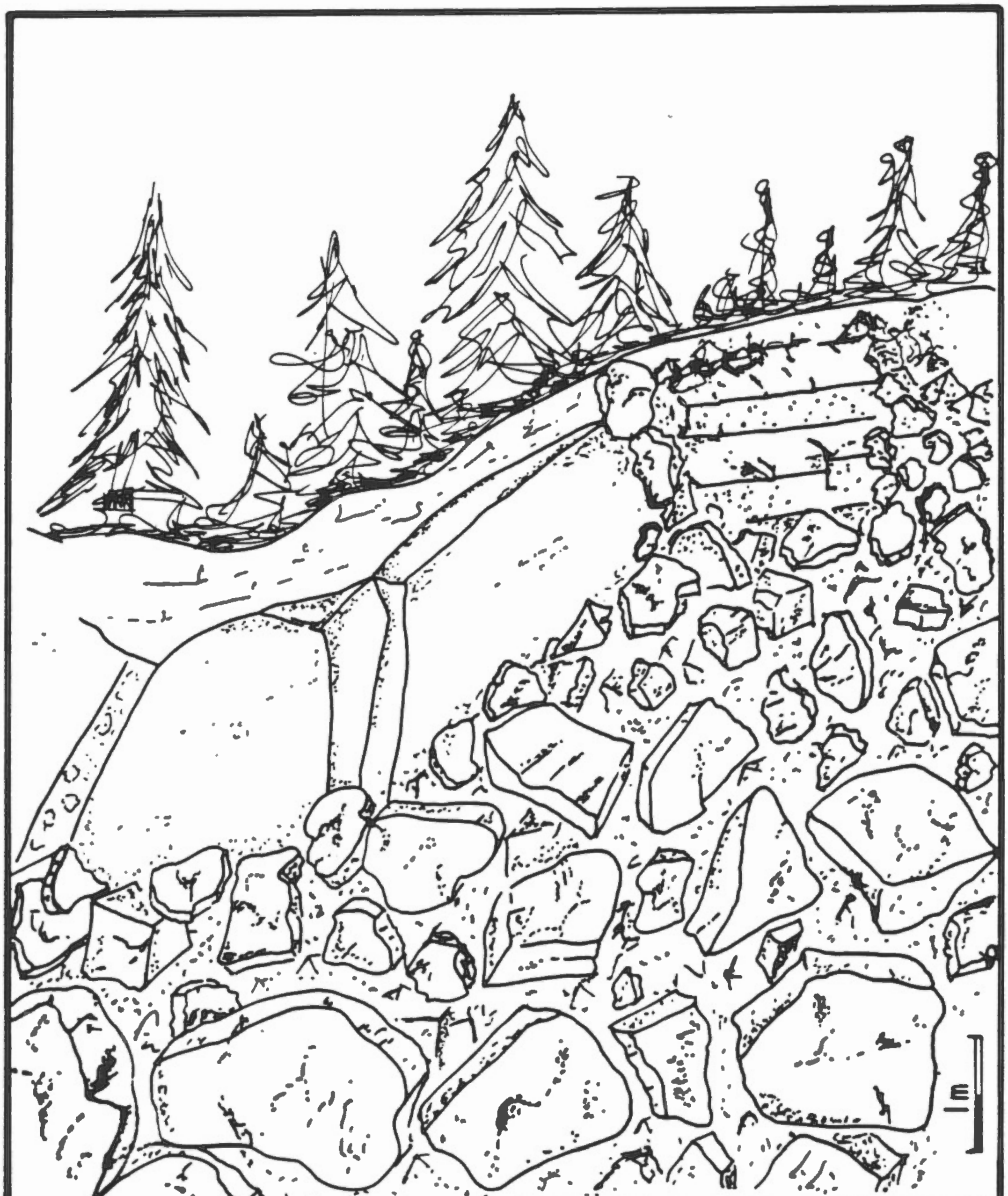


FIG.5 - 22C/7_4

FIGURE 6 - 22C/7-5

Field sketch of occurrence 22C/7-5. Pure galena and galena-calcite veins (black) as well as somewhat exaggerated, large disseminated galena grains (black) in calcareous conglomerate containing angular blocks of sandstone (stippled). Microscopic description of "zoned" galena vein refers to the major left-hand vein; euhedral galena grains in sandstone clast are also from the immediate vicinity of this vein.

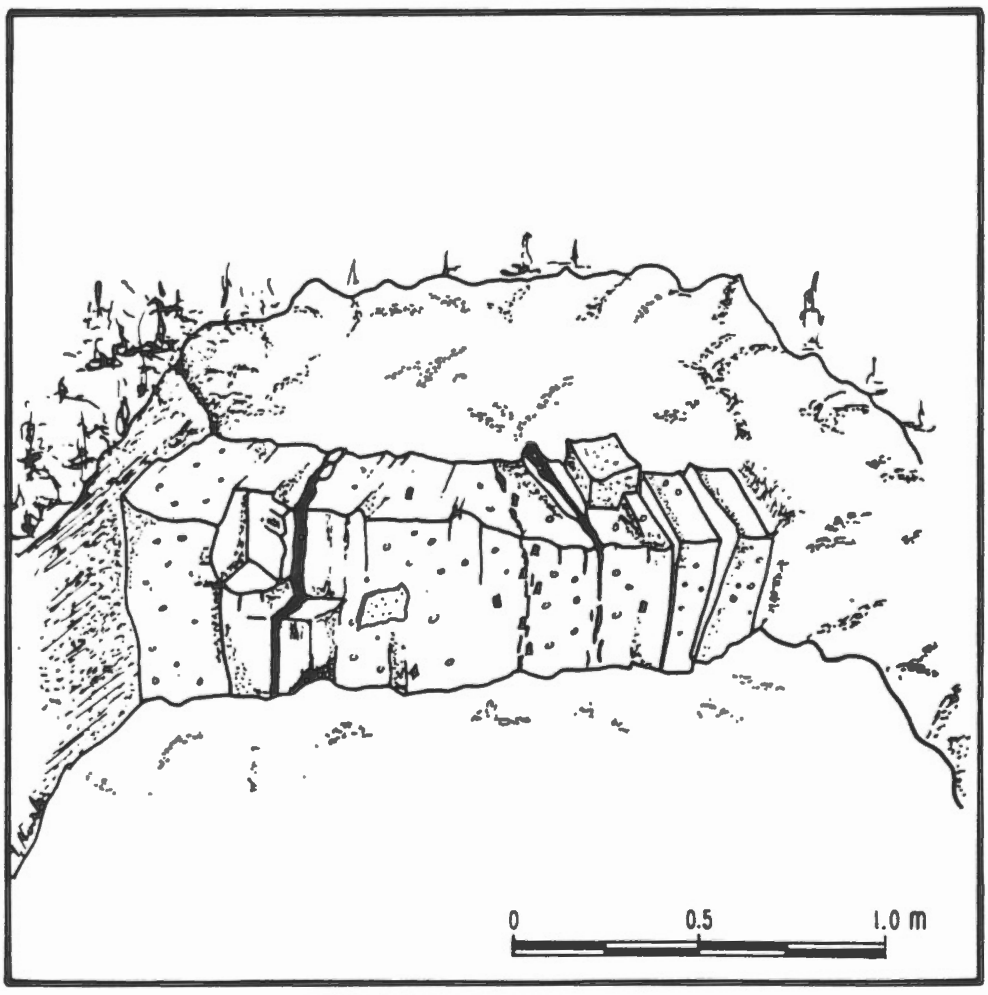


FIG. 6 — 22 C/7_5

FIGURE 7 - 22A/9-2

Field sketch of occurrence 22A/9-2(1). See field description in text. Microscopic description of zoning is from lower part of major left-hand vein.

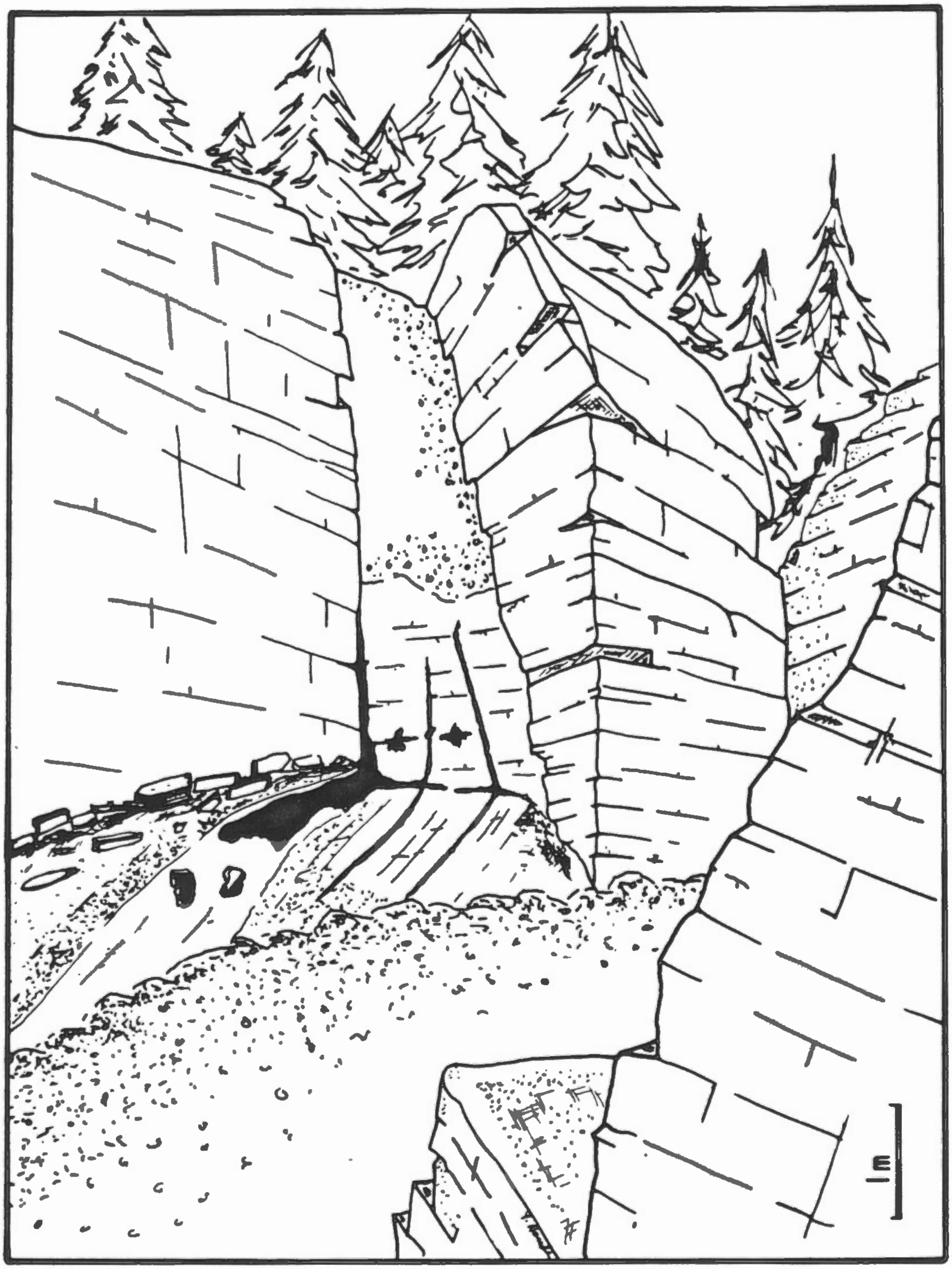


FIG. 7 — 22A/9_2

FIGURE 8 - 22A/16-4

Field sketch of occurrence 22A/16-4. Vein and relicts in solid black. See text for description. See also figure 9.

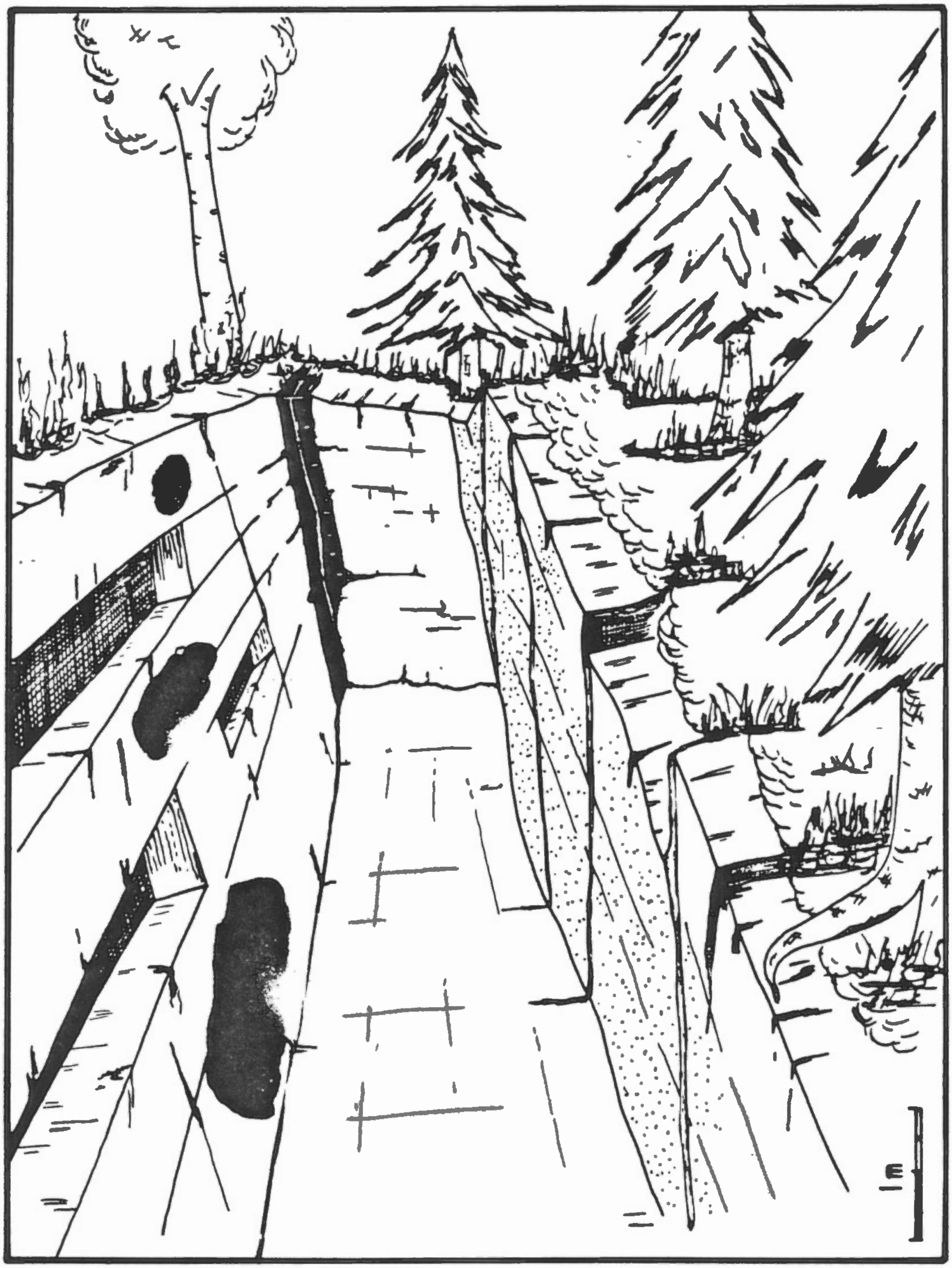


FIG.8 – 22 A / 16_4

FIGURE 9 - 22A/16-4

Sketch of cross-section of vein of occurrence 22A/16-4, showing central open space, comb-texture calcite in major part of vein, and finer-grained calcite selvedges. Galena (dashed) is virtually restricted to the selvedges.

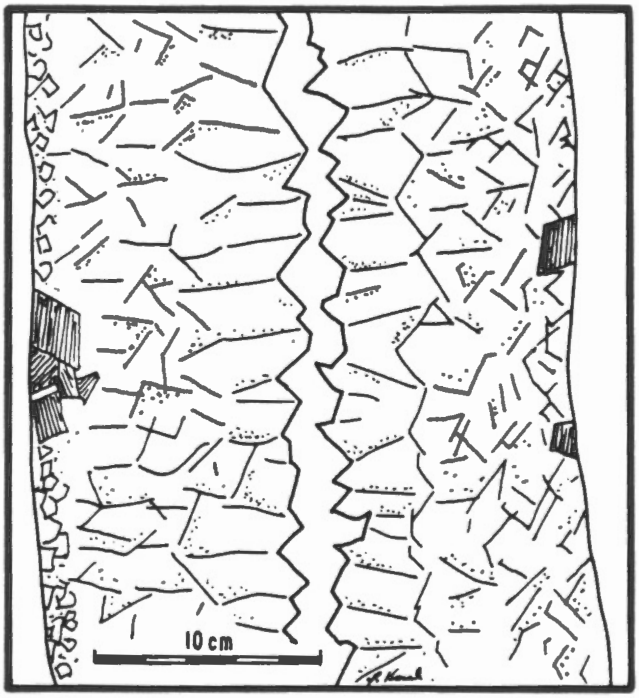


FIG. 9 – 22 A / 16_4

FIGURE 10 - 22A/16-6

Field sketch of occurrence 22A/16-6. Veins, exaggerated clearly defined (black) are made up, in fact, of aligned tension cracks. Samples studied under the microscope are from these veins, but precise location is not known.

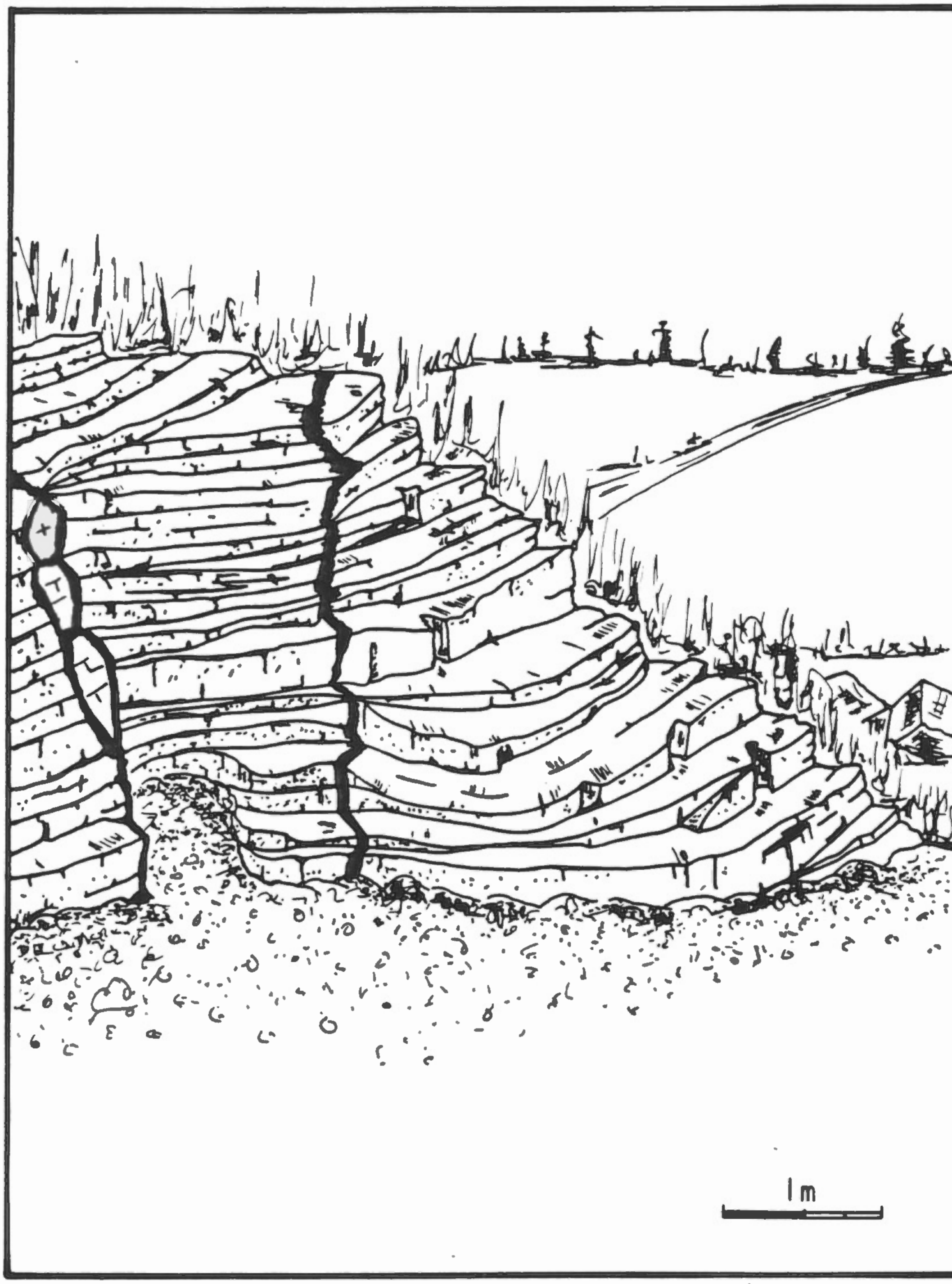


FIG. 10 — 22A/16_6

FIGURE 11 - 22H/4-1

Field sketch of occurrence 22H/4-1. See text for description; see also figure 12.

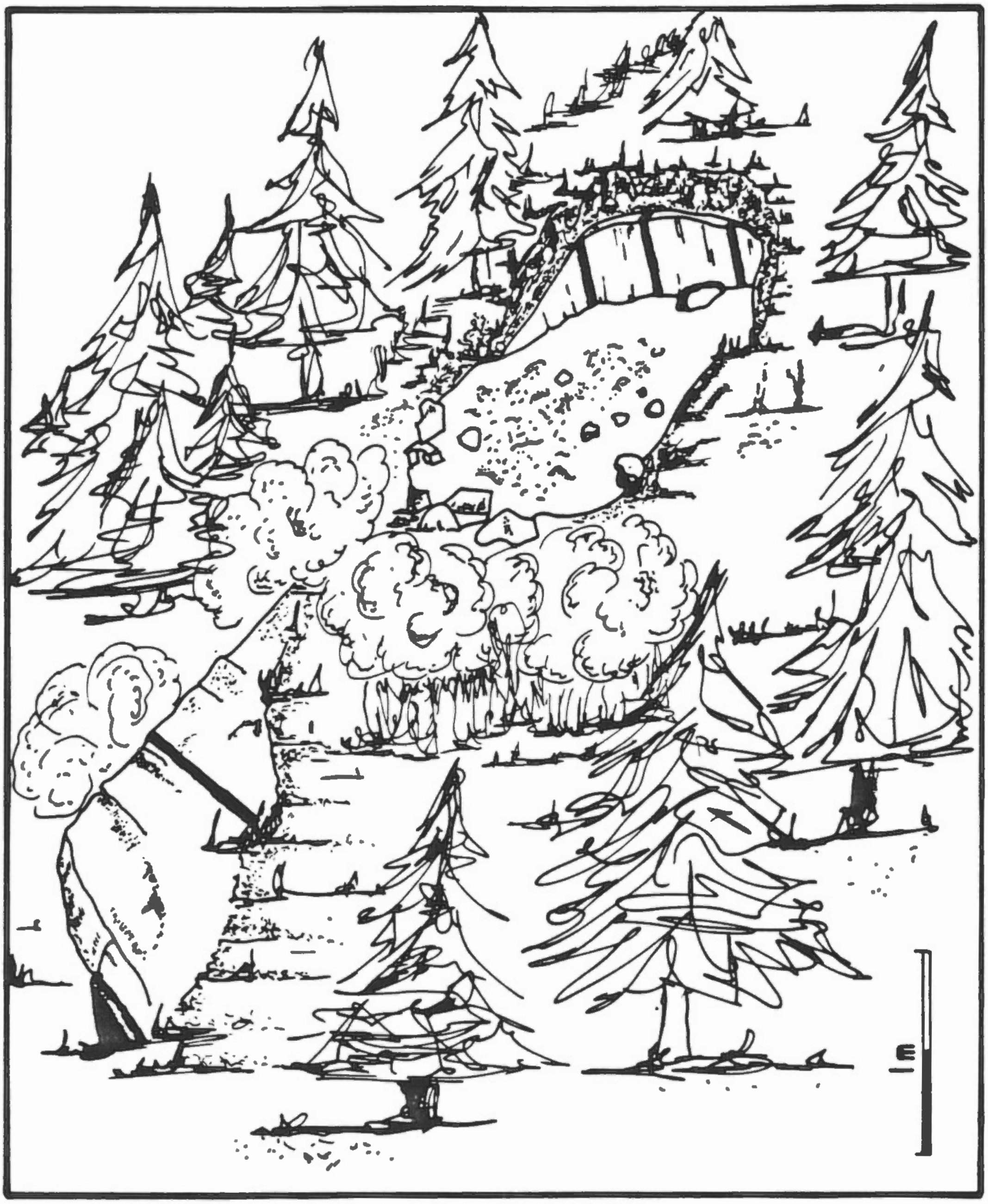


FIG. II-22H/4_1

FIGURE 12 - 22H/4-1

Sketch of specimen of about half cross-section of vein of occurrence 22H/4-1. See field description in text. The sample is from one of the upper three veins of figure 11; the microscopic description is based on samples from these veins as well, but not from the specimen shown.

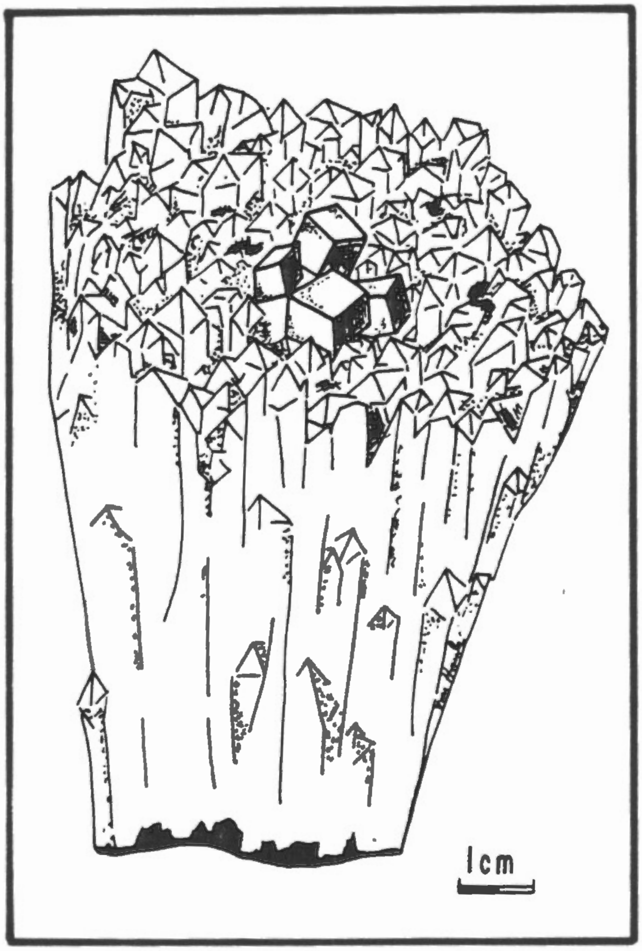


FIG. 12 – 22 H/4_1

FIGURE 13 - 22H/4-2

Field sketch of occurrence 22H/4-2. See text for description. Samples studied microscopically are from the top-most part of the two major veins.

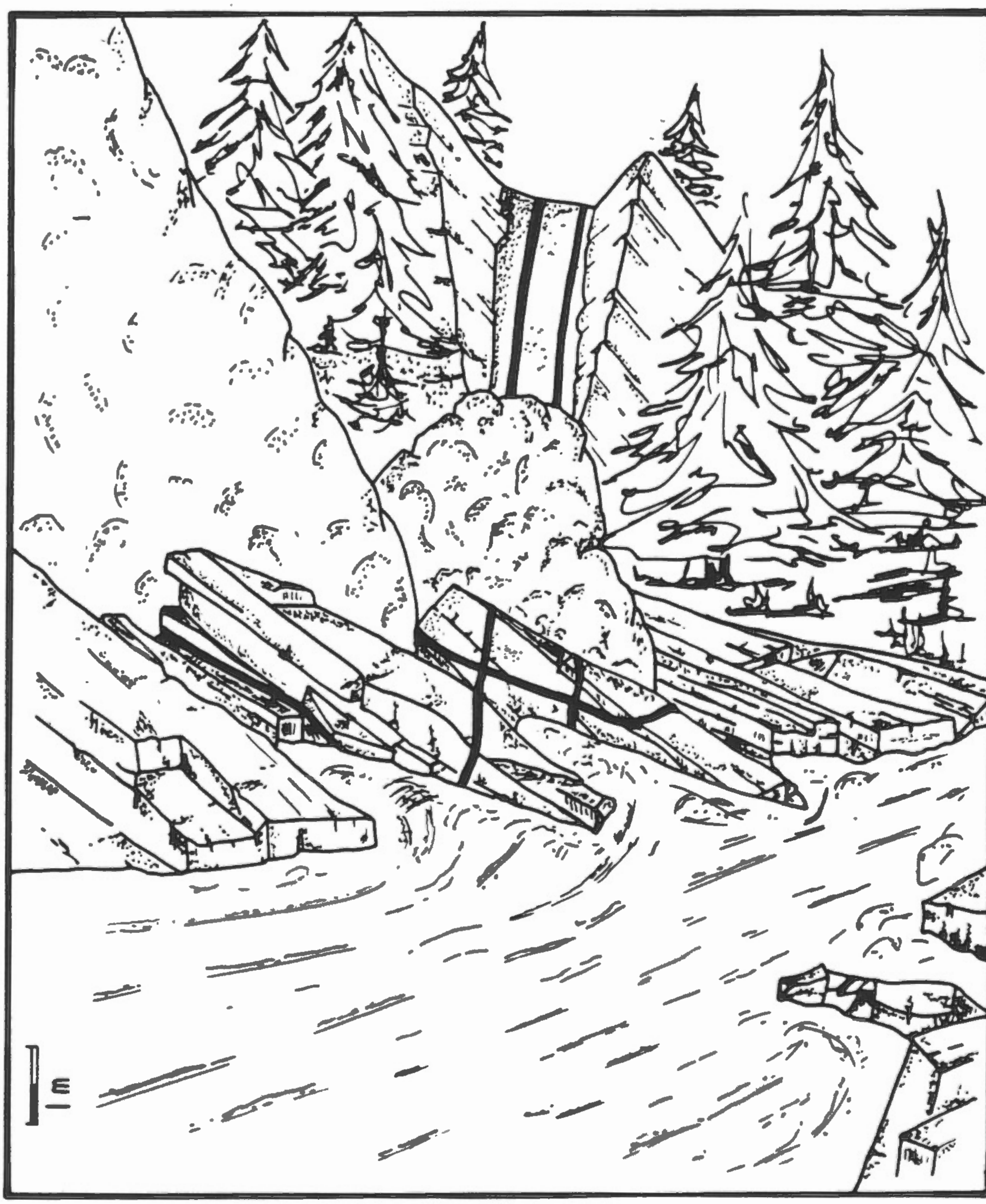


FIG. 13-22 H/4_2

PLATE I - 21N/13-6, 22C/7-4

A. Euhedral quartz in barite-galena vein (transmitted light; 21N/13-6). B. Quartz overgrowths and euhedral boundaries of detrital quartz grains of sandstone host only where grains are in contact with vein (transmitted light; 21N/13-6). C. Barite fills fracture in quartz grain of sandstone host (transmitted light; 21N/13-6). D. Inclusion of mylonitic quartz in well crystallized barite host (transmitted, cross-polarized light; 22C/7-4).

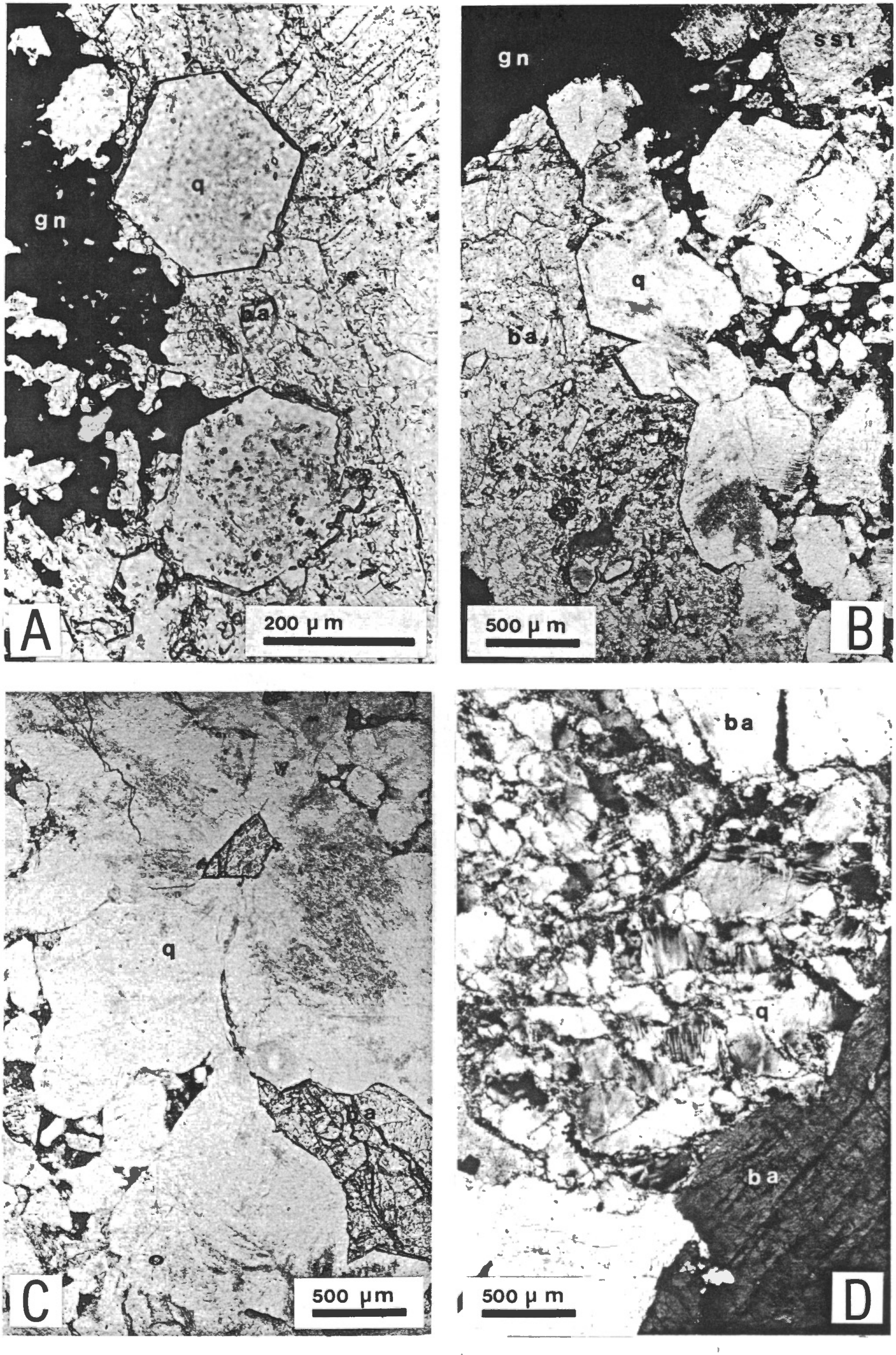
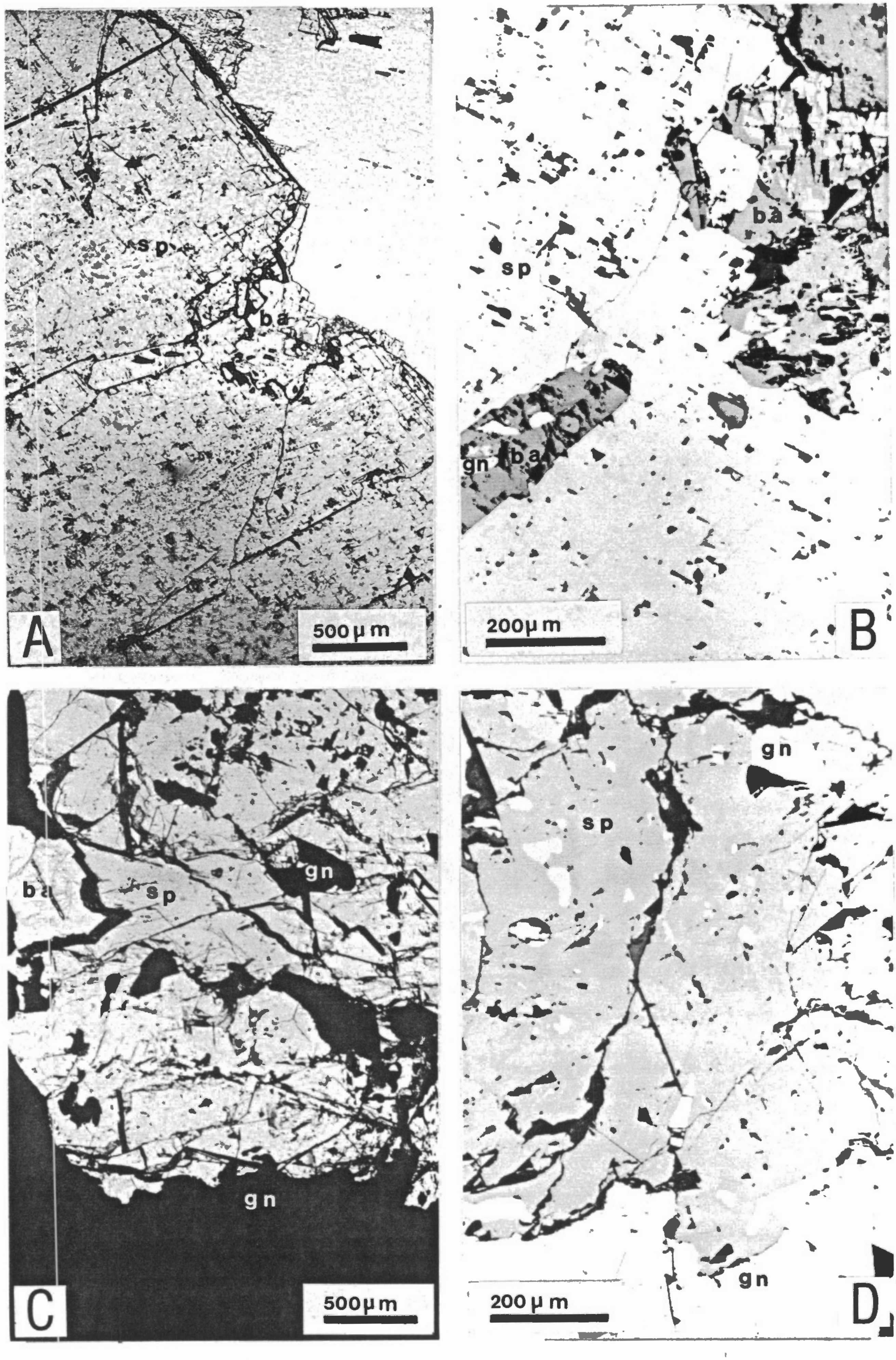


PLATE _ I 21N/13_6; 22C/7_4

PLATE II - 21N/13-6

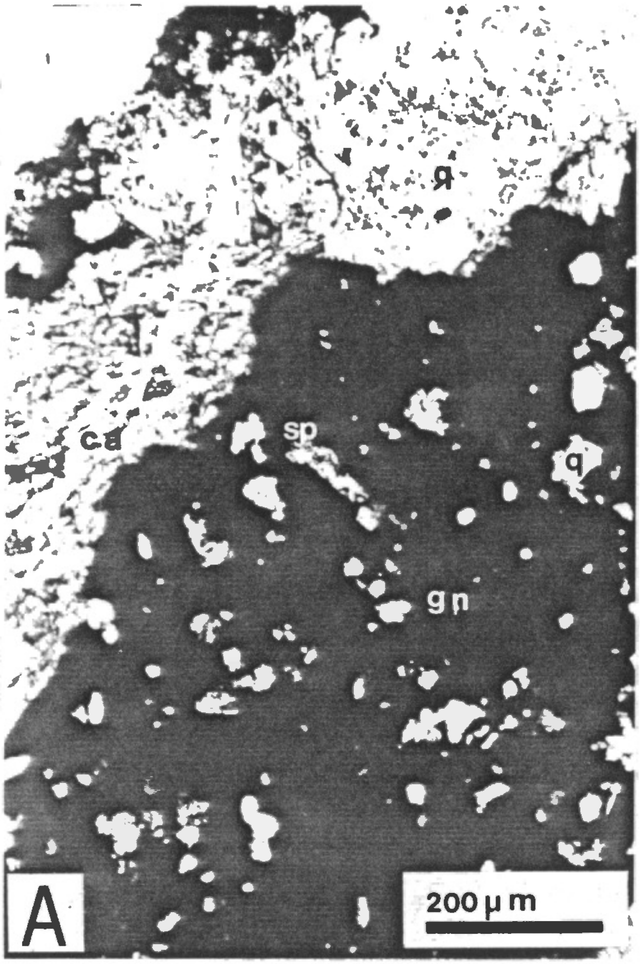
<u>A.</u> Barite apophysis and inclusion (?) in sphalerite; black specks enclosed in barite are galena (transmitted light). <u>B.</u> Detail of A (reflected light). <u>C.</u> Irregular contact between galena and sphalerite; latter contains numerous anhedral inclusions of galena (transmitted light). <u>D.</u> Detail of C (reflected light).

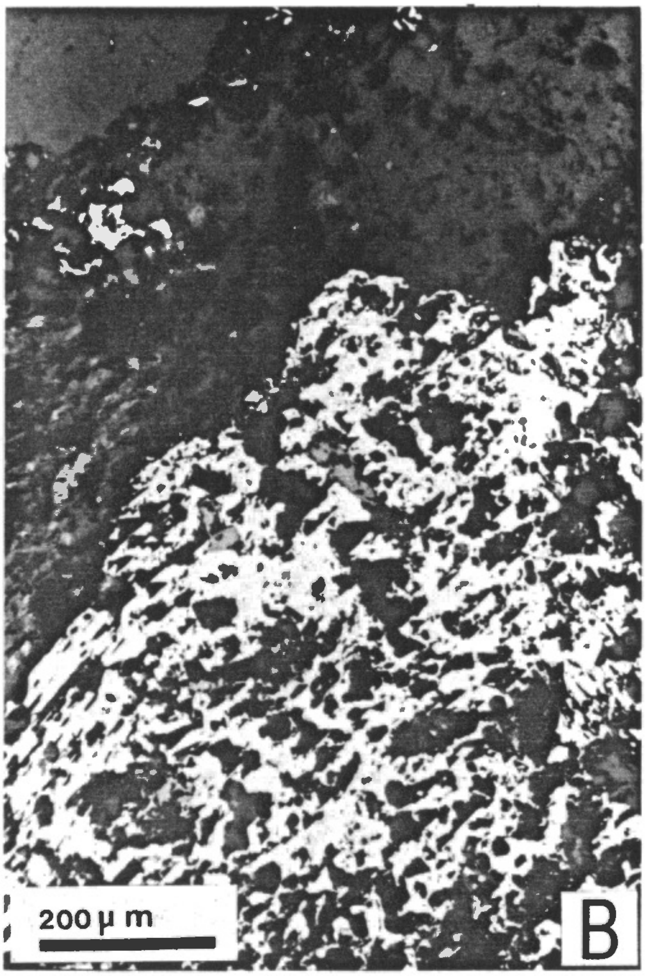


PLATE_II 2IN/13_6

PLATE III - 22C/7-5

A. Galena in calcite - quartz vein; galena contains inclusions of quartz and anhedral sphalerite grains (transmitted light). B. Same field of view (reflected light). C. Euhedral galena crystals in sandstone clast of calcareous conglomerate (transmitted light).

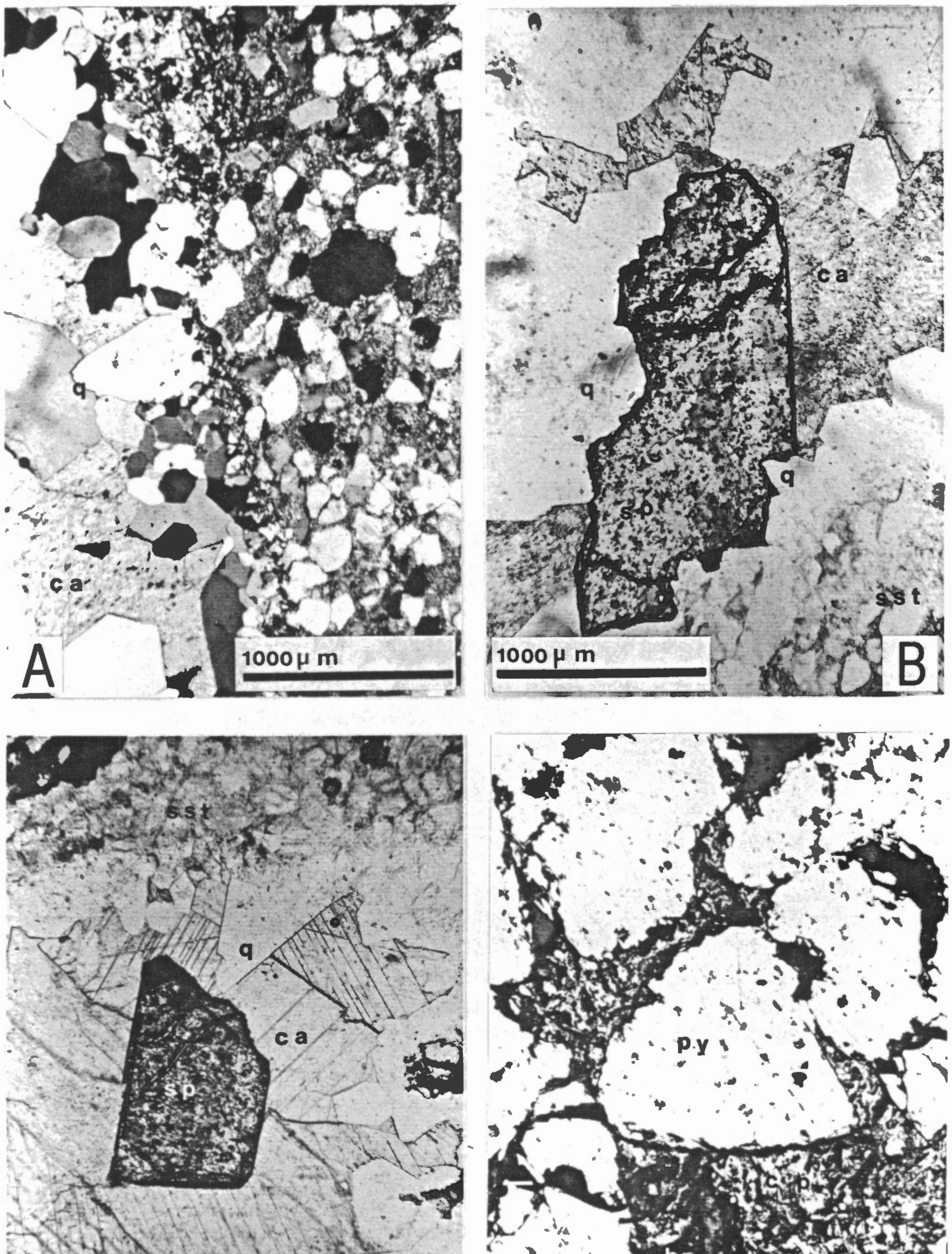




PLATE_III 22C/7_5

PLATE IV - 22B/12-13

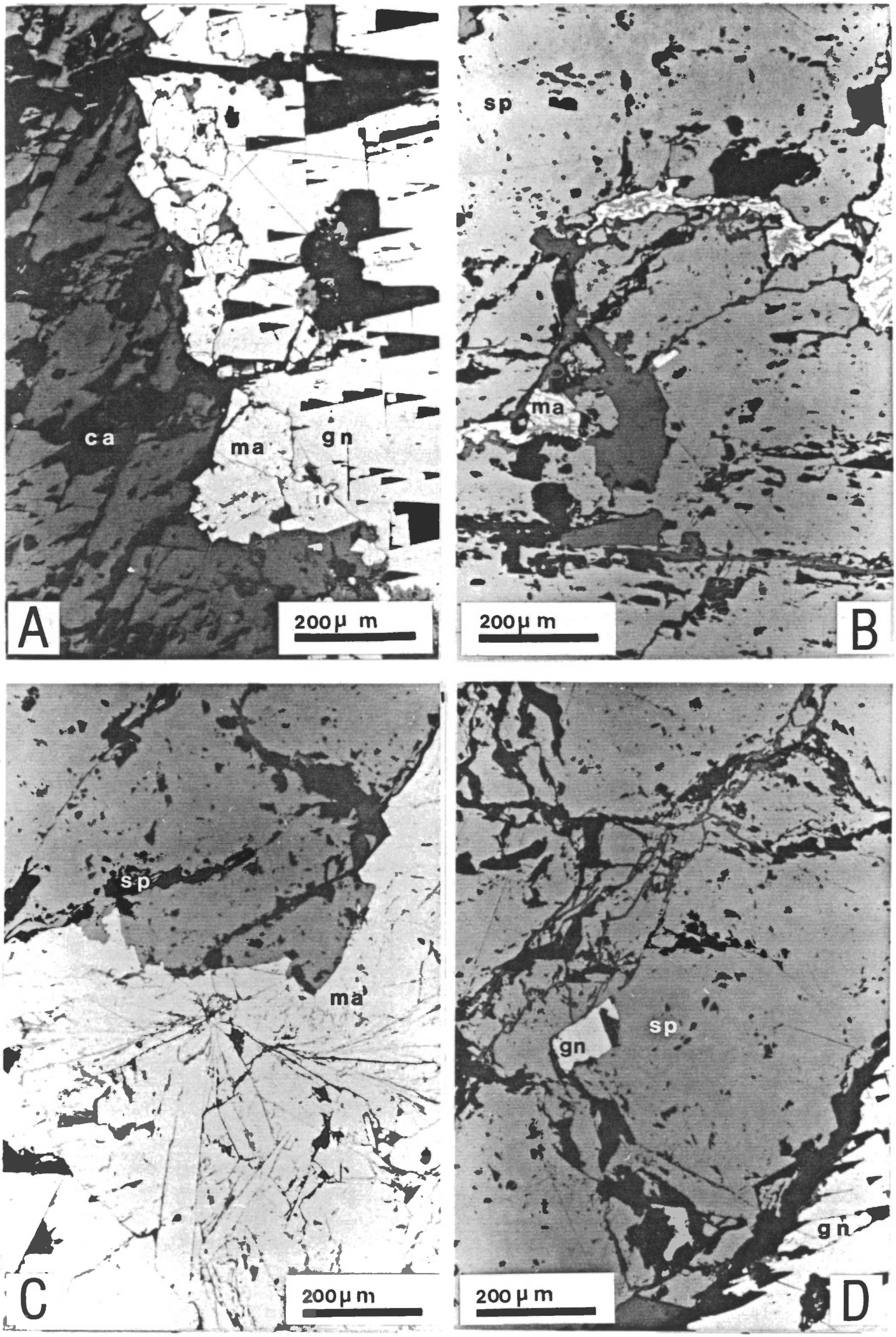
A. Euhedral quartz and anhedral calcite fill vug in sandstone host; the fine-grained zone separating host and vug suggests dissolution during vug-filling (transmitted, cross-polarized light). B. Contiguous part of same vug with major sphalerite crystal showing its own crystal boundary against anhedral calcite, but not against euhedral quartz (transmitted light). This suggests late filling of quartz-lined vug by calcite and sphalerite. C. Sphalerite bounded by its own crystal faces where in contact with calcite, but not where contacting protrusion of quartz prism (transmitted light). D. Pyrite grain cut by chalcopyrite-bornite stringers (reflected light).



PLATE_IV 22B/12_13

PLATE V - 22A/9-2

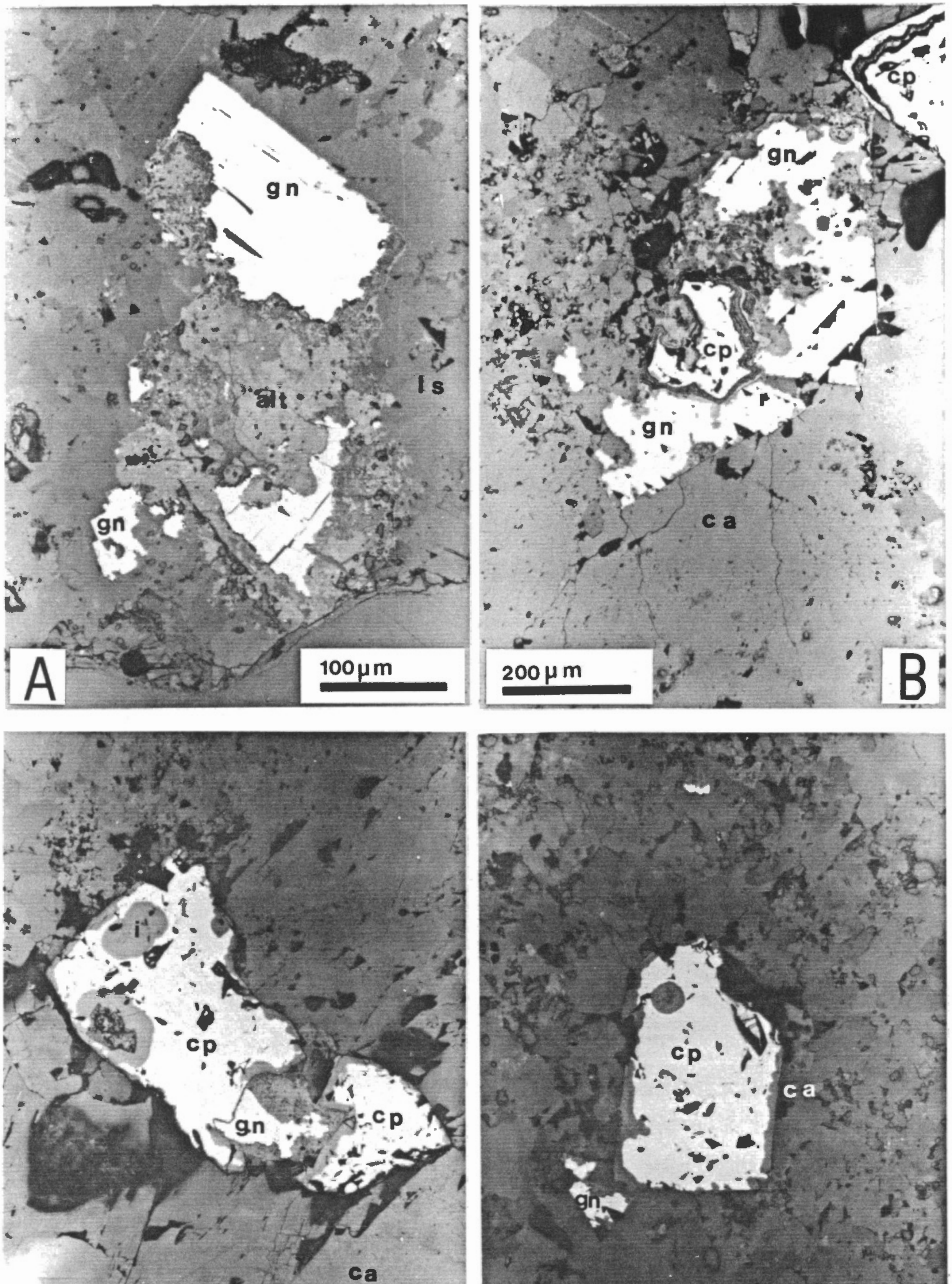
A. Marcasite lines boundary between carbonate gangue and galena (reflected light). B. Partially oxidized marcasite stringers enclosed in sphalerite (reflected light). C. Bladed texture of partially oxidized marcasite in contact with sphalerite (reflected light). D. Rare galena inclusion in sphalerite (reflected light).



PLATE_V 22A/9_2

PLATE VI - 22A/16-4

A. Partial replacement of galena crystal by dull-grey, semi-metallic aggregate containing traces of chalcopyrite and covellite (reflected light). B. Marginally oxidized chalcopyrite grain partly enclosed in galena crystal (reflected light). C. Altered galena grain in partially oxidized chalcopyrite; note that the outline of the entire aggregate suggests advanced replacement of galena by chalcopyrite (reflected light). D. Marginally oxidized chalcopyrite grain, outline of which suggests complete replacement of galena (reflected light). B, C and D are from a single section of a small sample, exceptionally rich in chalcopyrite, of the vein.



PLATE_VI 22A/16_4

PLATE VII - 22A/16-4

A. Destruction of galena crystal in a carbonate vein by a dull grey semi-metallic aggregate (reflected light; "alt" = Pb oxide or Pb hydroxide). B. Pyrite (or marçasite) coating along contact of vein-bound galena crystal and wall rock (reflected light).

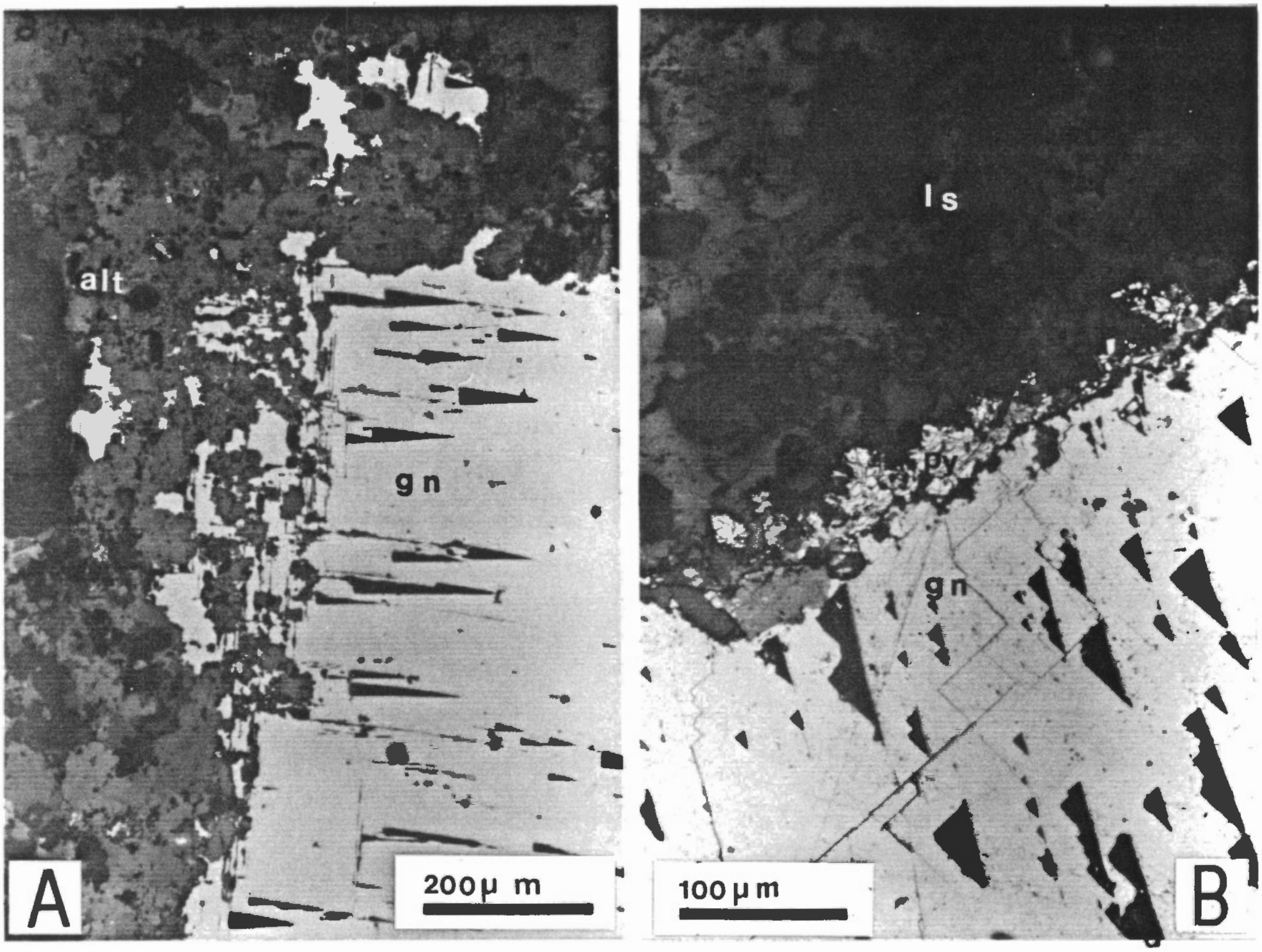
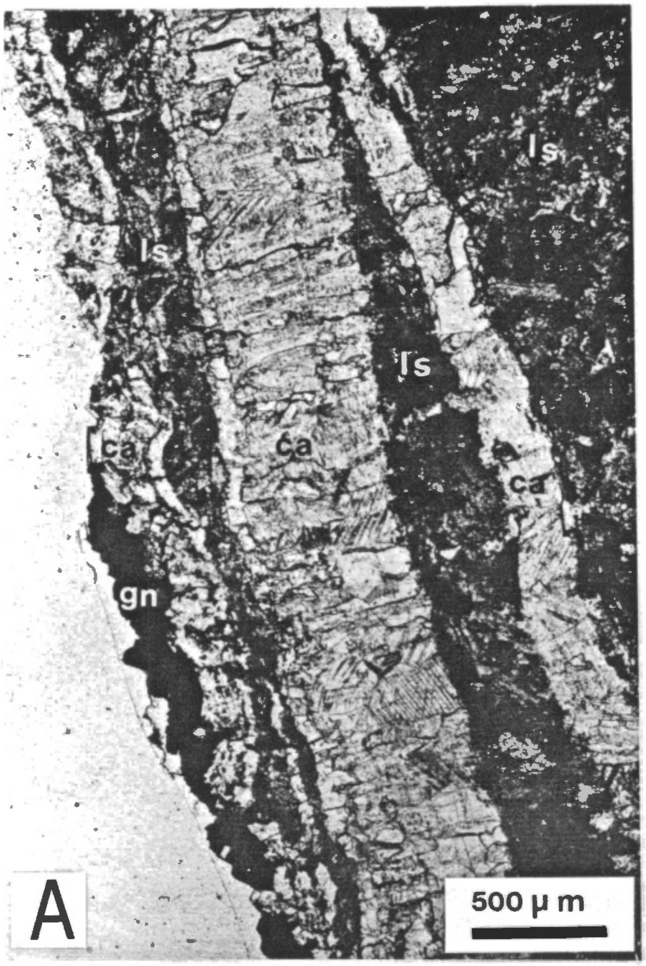
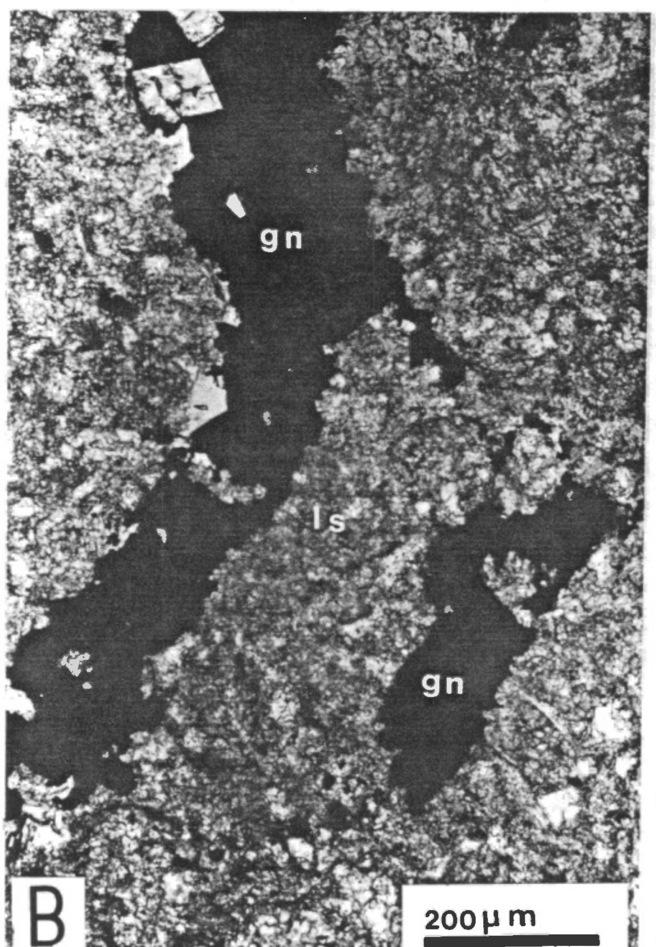


PLATE _ VII 22A/16_4

PLATE VIII - 22A/16-6

A. Principal mode of occurrence of galena in, or contiguous to, comb-textured carbonate vein in limestone (transmitted light). B. Second mode of occurrence of galena: in stringers in host rock and intergrown with rare euhedral carbonate gangue (transmitted light). C. Same field of view as B (reflected light).





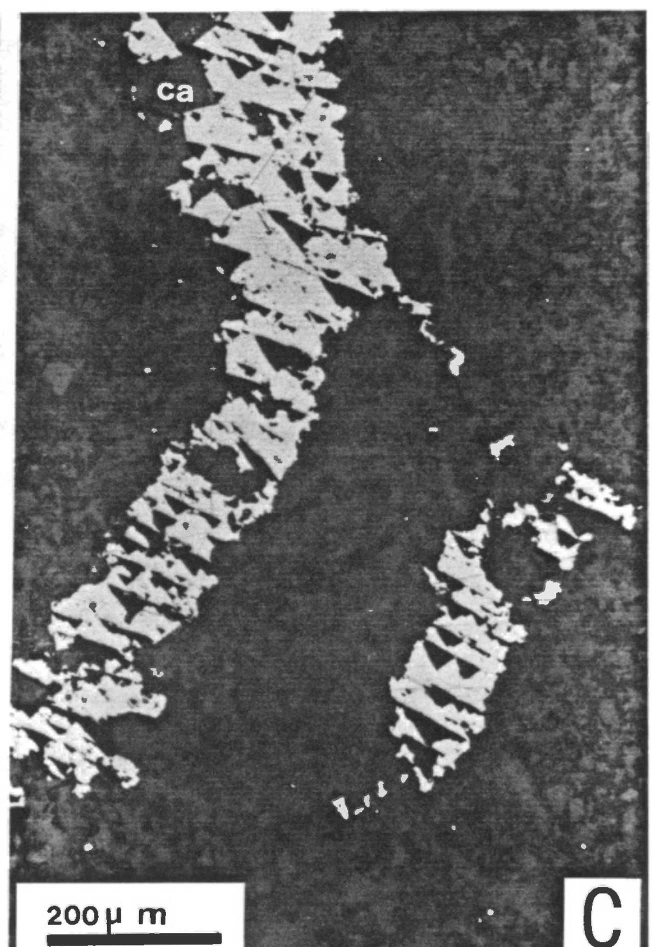


PLATE _ VIII 22A/16_6

PLATE IX - 22A/16-6

A. Spar-filled birdseye in limestone (transmitted light). B. Three galena-mantled sparry bodies in limestone, 4 cm from carbonate-galena vein of fig. VIIIA (transmitted light). C. Detail of one of the bodies shown in B (transmitted light). D. Same field of view as C (reflected light). Note similarity in scale of A and C. This plate illustrates third mode of occurrence of galena and suggests replacement of spar by galena.

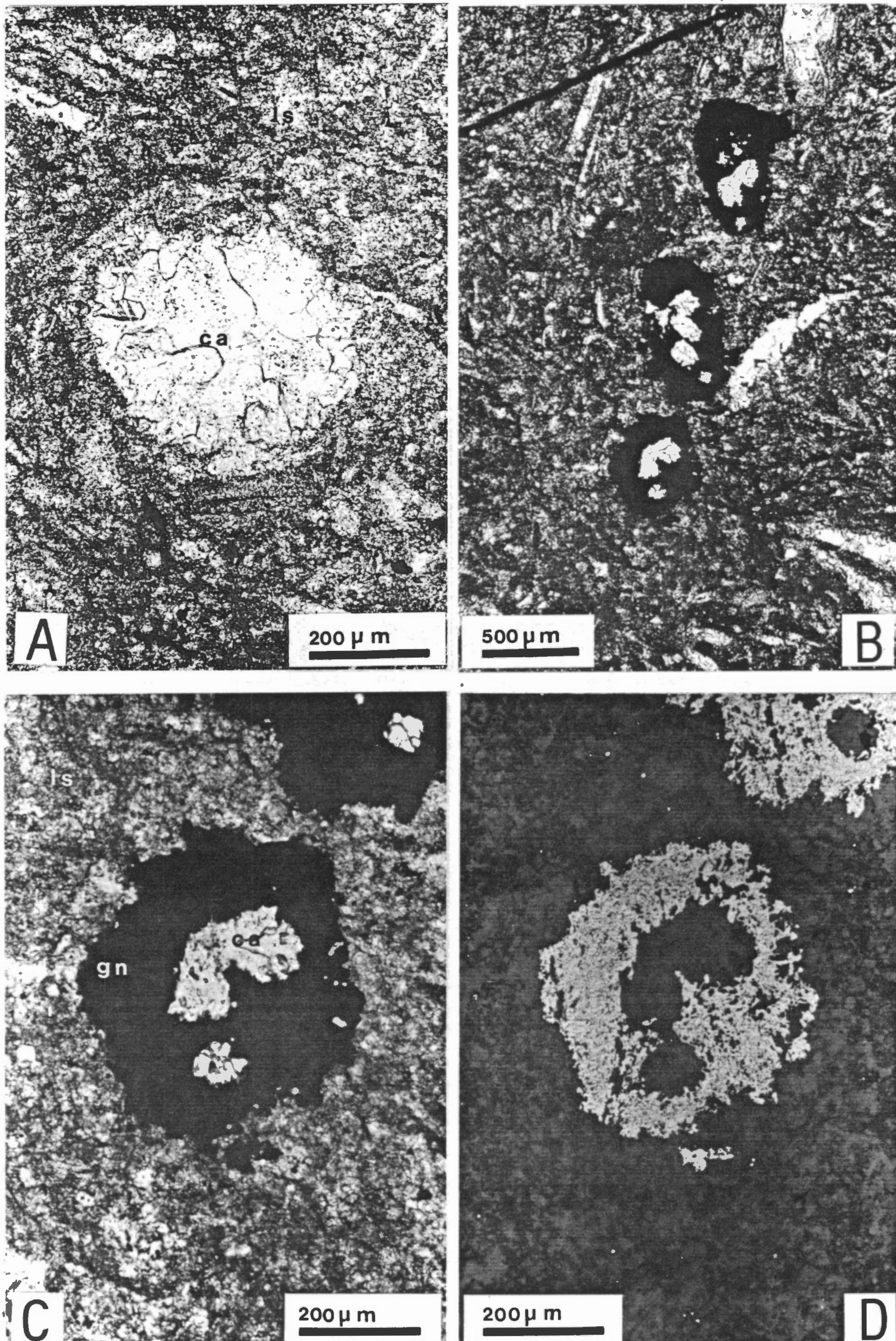


PLATE _ IX 22A/16_6

PLATE X - 22H/4-1

A. Aggregate of carbonate-galena-sphalerite in selvedge of quartz vein; note that carbonate crystals are zoned parallel to contacts with sulfides; zones are outlined by cryptocrystalline matter, probably iron-oxyhydroxides (transmitted light). Details in Plate XI. B. Similar intimate association of galena and sphalerite with "dusty" and zoned carbonate crystal in prismatic gangue quartz (transmitted light). C. Detail of B (reflected light). D. Same field of view as C (transmitted light). This plate suggests the moulding of sulfides by pre-existing carbonate rhombs ("saddle" dolomite/ankerite?).

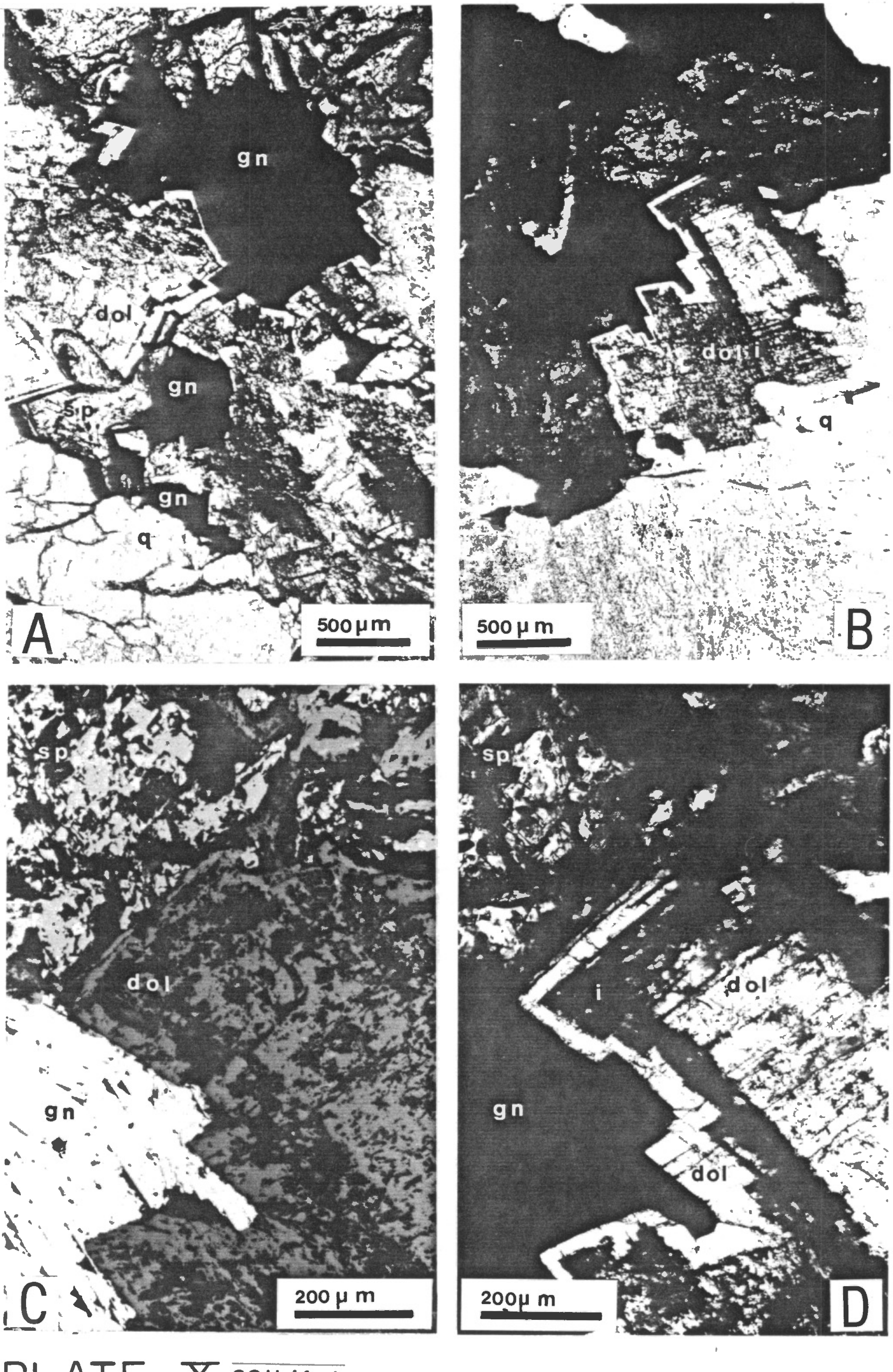


PLATE X 22H/4-I

PLATE XI - 22H/4-1

A. Detail of Plate XA (transmitted light). B. Same field of view as A, suggesting replacement or infiltration of carbonate by diffuse stringers and patches of anhedral galena (reflected light). C. Detail of Plate XA (transmitted light). D. Same field of view as C, suggesting either replacement of carbonate by galena or filling of pore space remaining after carbonate precipitation.

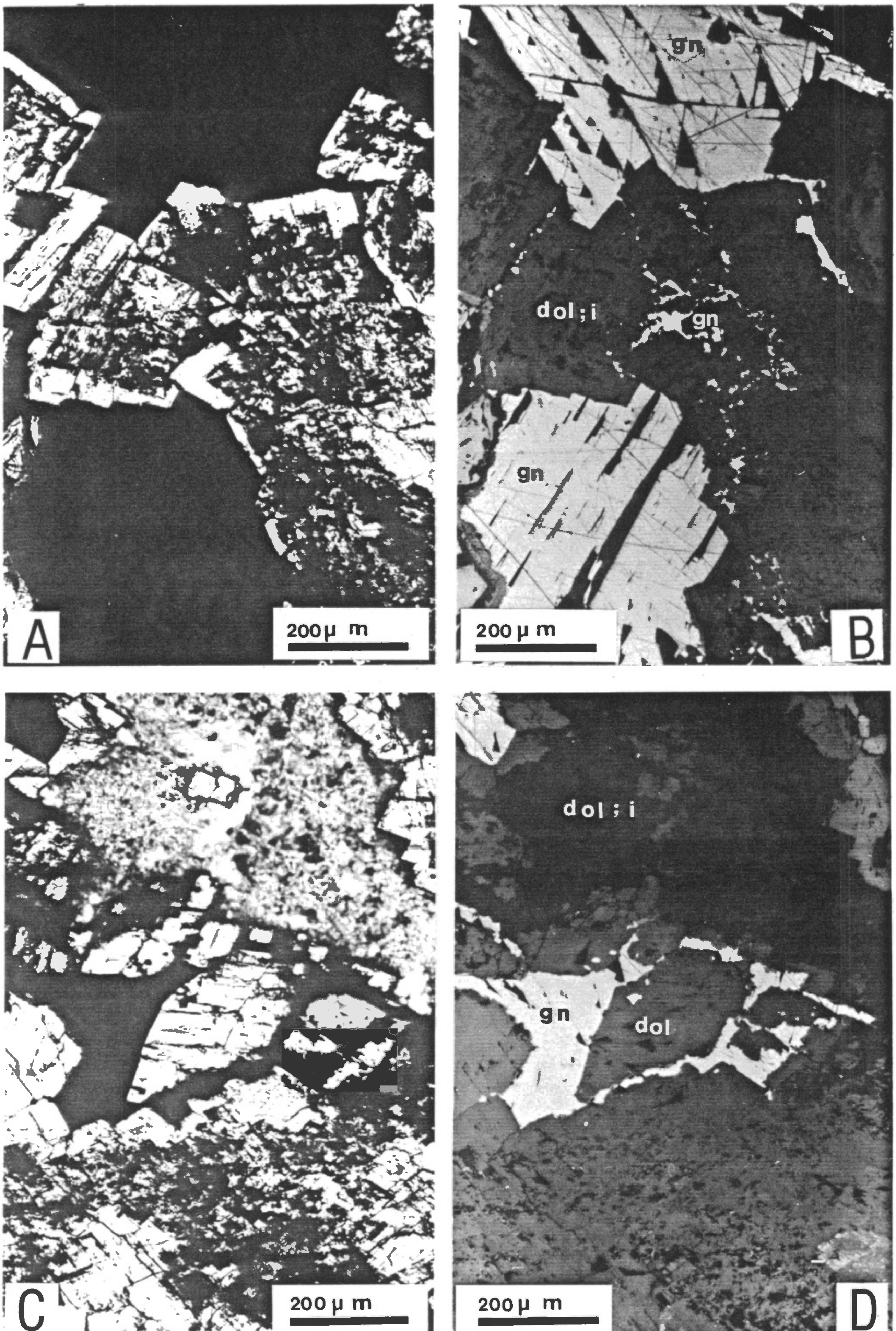
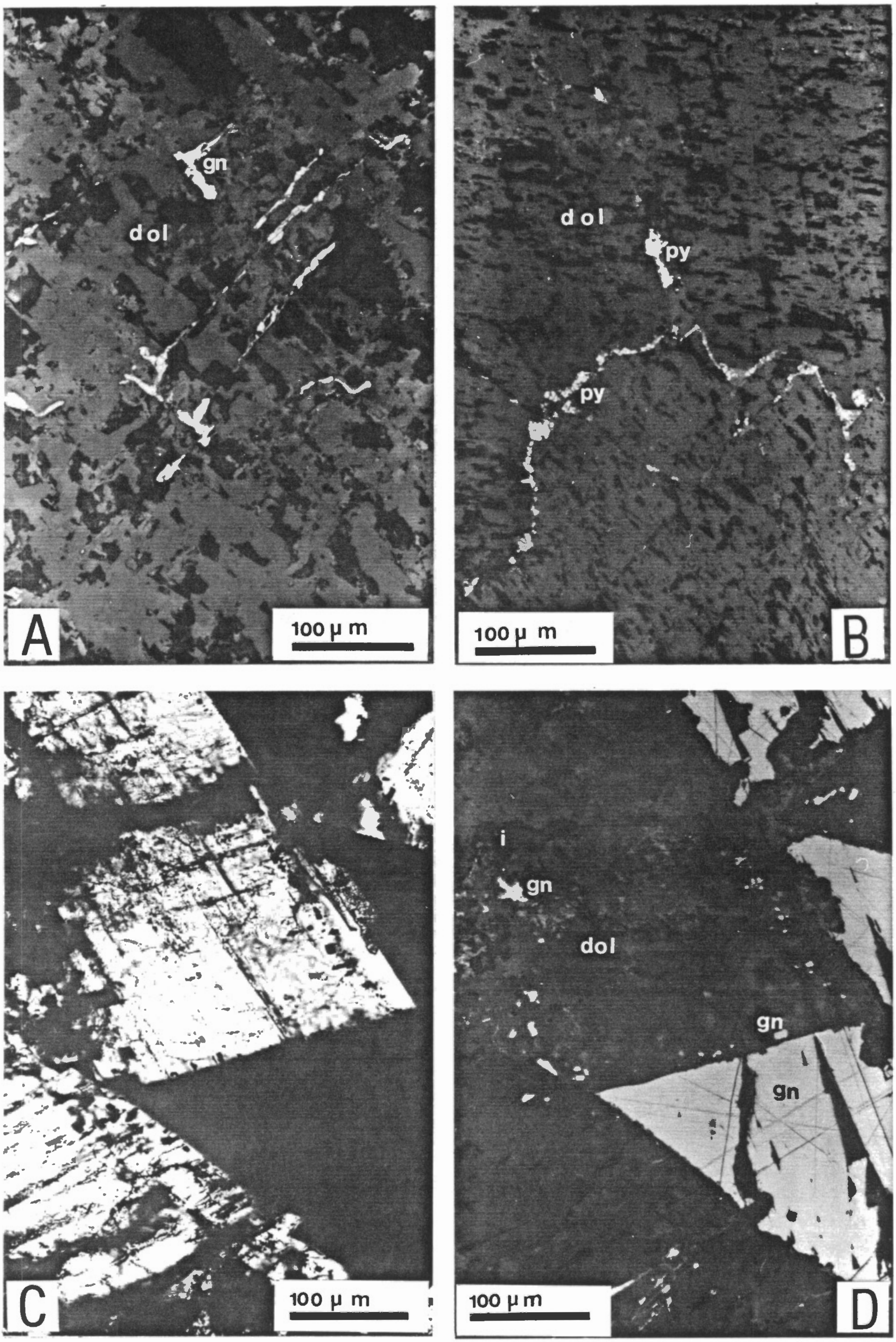


PLATE _ XI 22H/4_I

PLATE XII - 22H/4-1

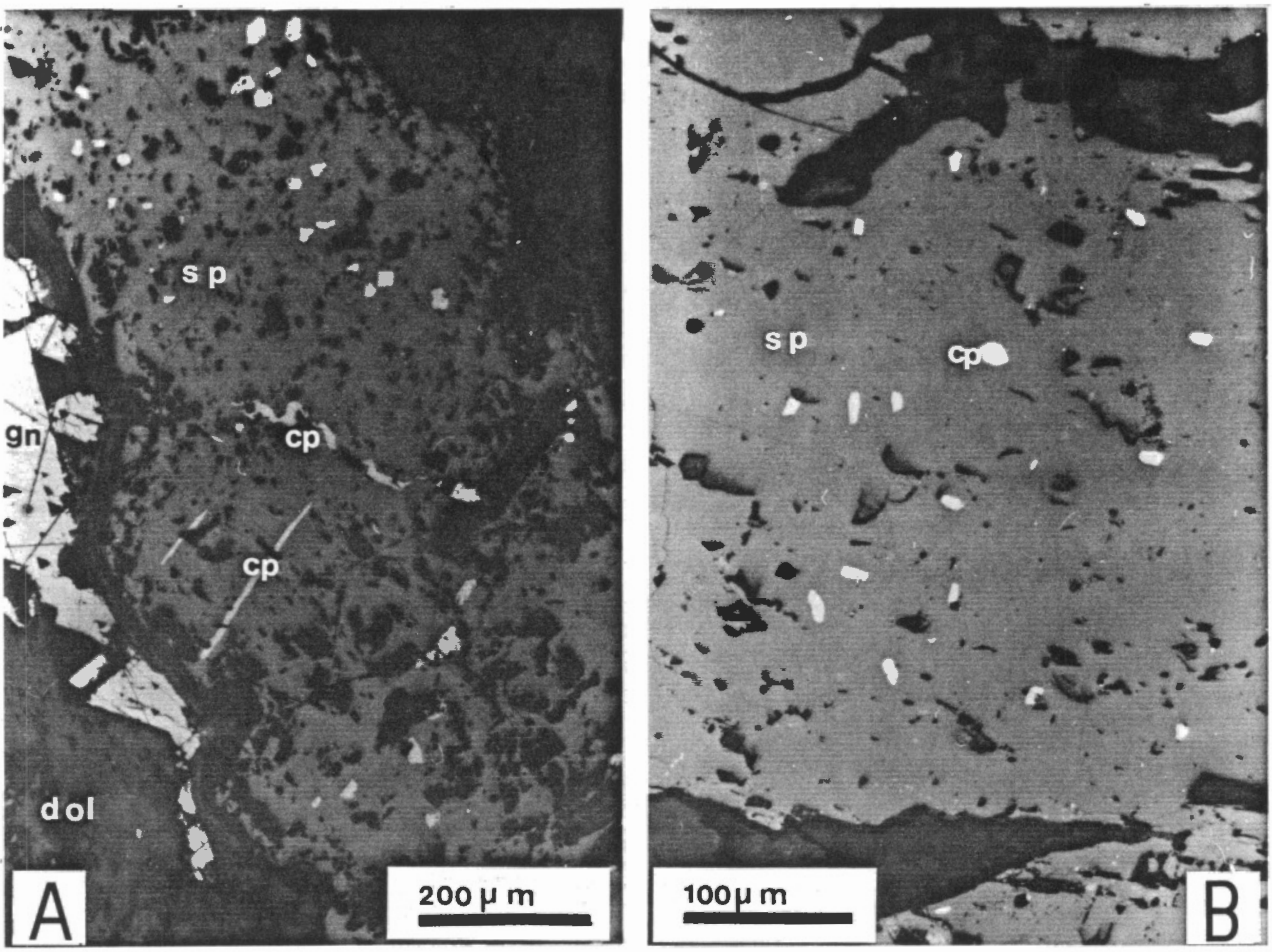
A. Galena stringers cutting across gangue-carbonate crystal parallel to cleavage directions (reflected light). B. Pyrite stringer separating two gangue-carbonate crystals; latter contain rare inclusions of pyrite (reflected light). C. Remarkable alignment of galena inclusions in carbonate parallel to contact between galena and carbonate crystal (transmitted light). D. Same field of view as C (reflected light).



PLATE_XII 22H/4_1

PLATE XIII - 22H/4-1

A. Curvilinear and linear chalcopyrite stringers as well as roughly aligned chalcopyrite grains in sphalerite (reflected light). B. Most common habit of chalcopyrite inclusions in sphalerite (reflected light).



PLATE_XIII 22H/4_1

PLATE XIV - 22H/4-2

A. Part of base of galena "pyramid" rooted in selvedge of quartz vein in shale (transmitted light). B. Area near summit of galena pyramid of A; on either side of the galena, a prism of quartz is aligned parallel to the galena (transmitted light). C. Area between base and summit of the galena pyramid of A and B, showing apparent deformation although quartz on either side is not strained and shows straight extinction (reflected light). This suggests lattice distortion during the growth of galena; entire pyramid is part of one crystal (cleavage and pits are continuous throughout). D. Entire sphalerite "pyramid", rooted in selvedge of opposite side of same quartz vein; center and summit of pyramid are parallel to contiguous quartz prisms (transmitted light).

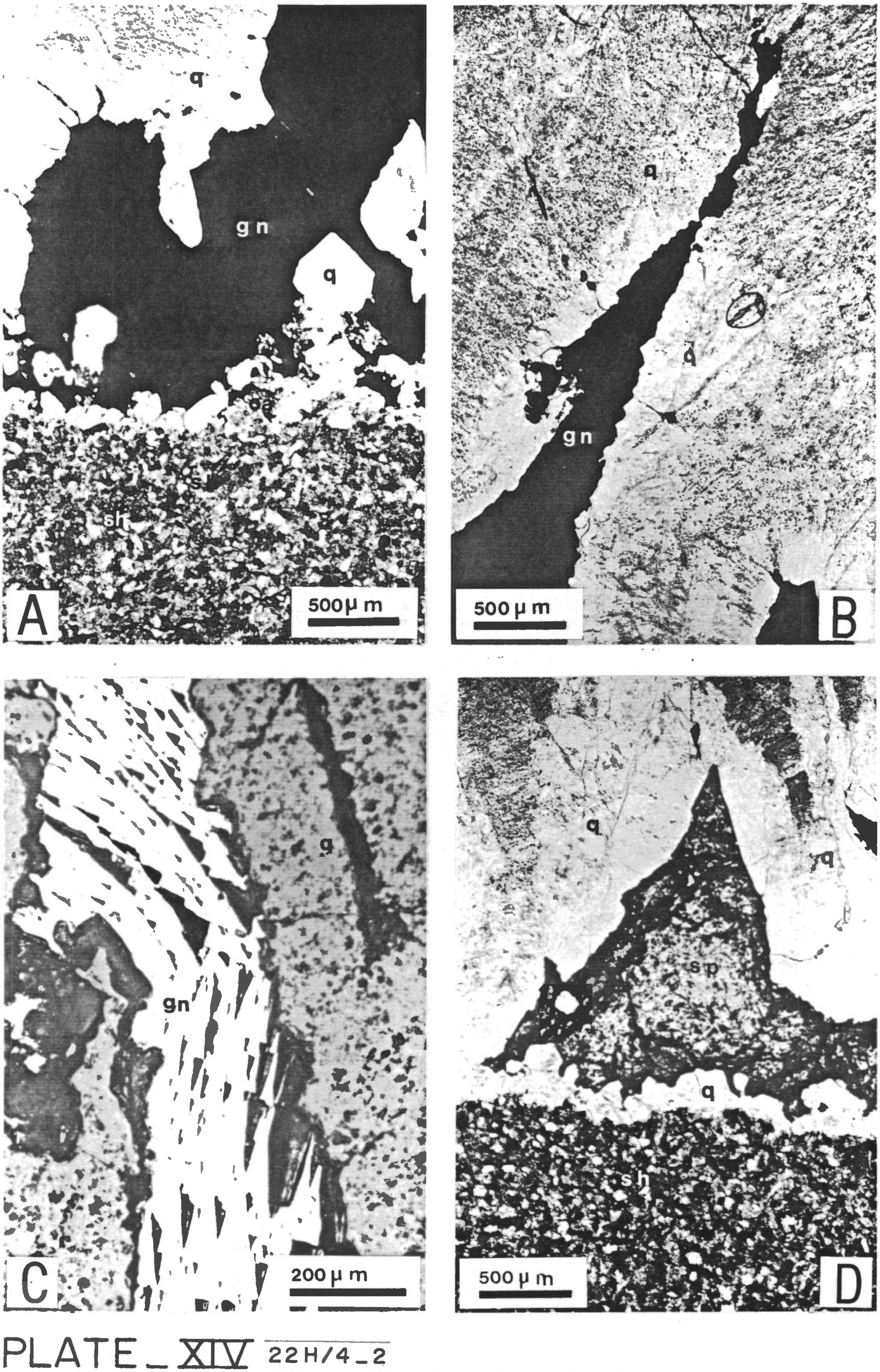
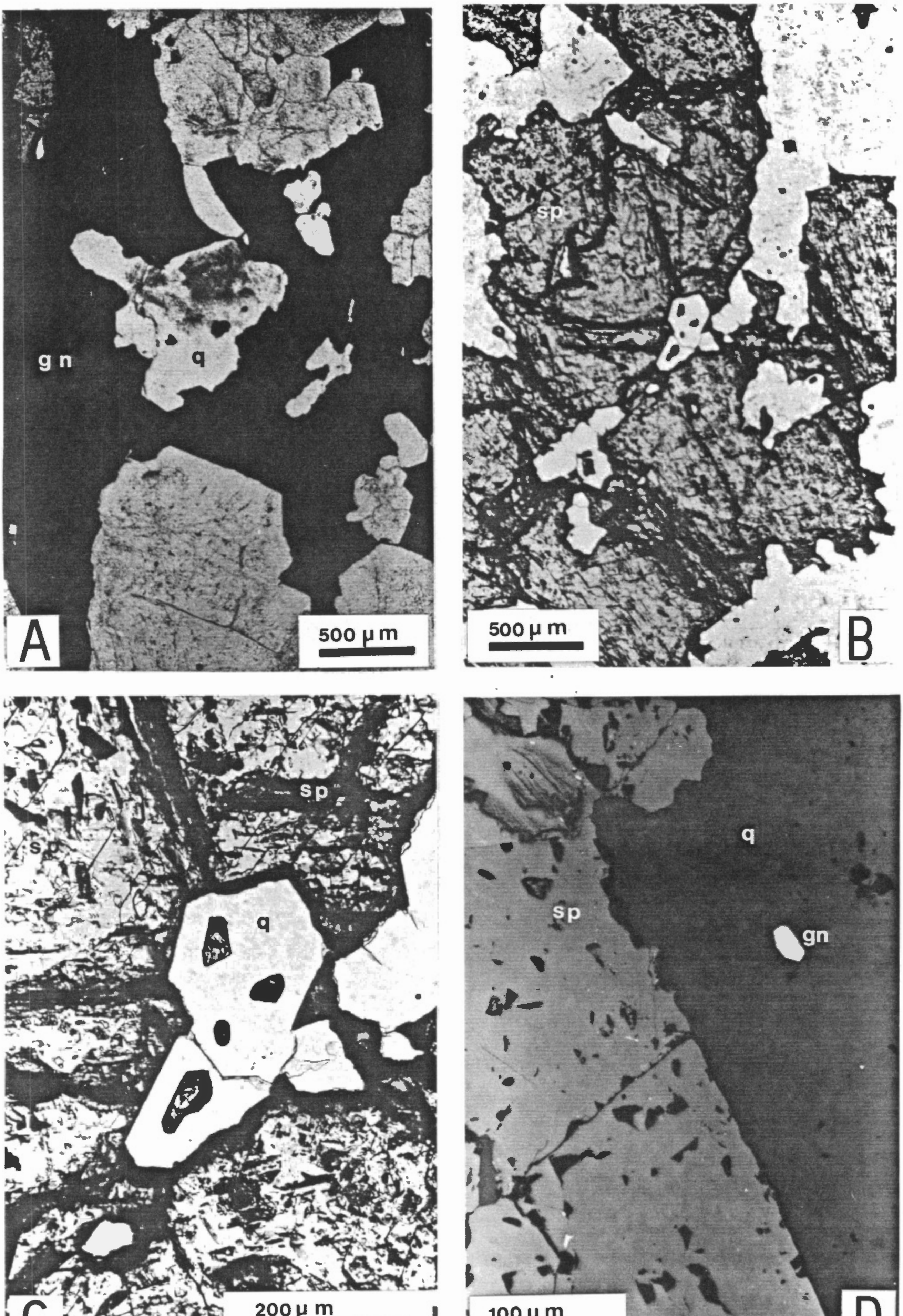


PLATE _ XIV 22H/4_2

PLATE XV - 22H/4-2

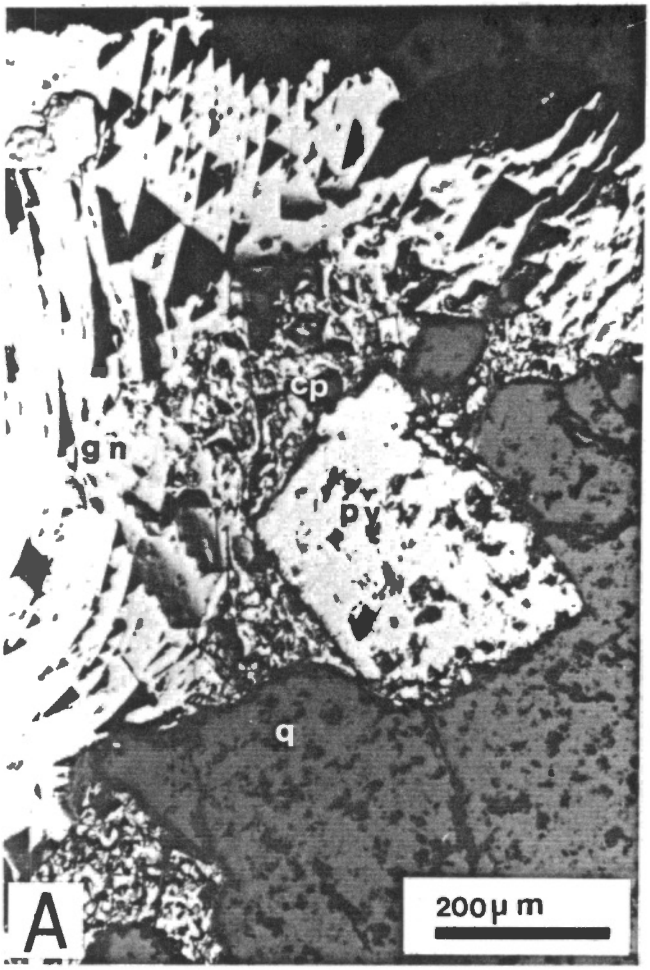
A. Poikilitic galena grain enclosing subhedral and euhedral quartz crystals; the black specks in the central quartz crystal are grains of galena (transmitted light). B. Poikilitic sphalerite grain, enclosing euhedral quartz crystals; the specks in the quartz crystals are sphalerite grains (transmitted light). C. Detail of B (transmitted light). D. Euhedral galena crystal enclosed in euhedral quartz which, in turn, is enclosed in major sphalerite crystal (reflected light).



PLATE_XV 22H/4_2

PLATE XVI - 22H/4-2

A. Galena replaced by chalcopyrite in zone between galena and pyrite crystal (reflected light). B. Discontinuous galena stringer in sphalerite, connecting major galena crystals on either side of sphalerite (reflected light).



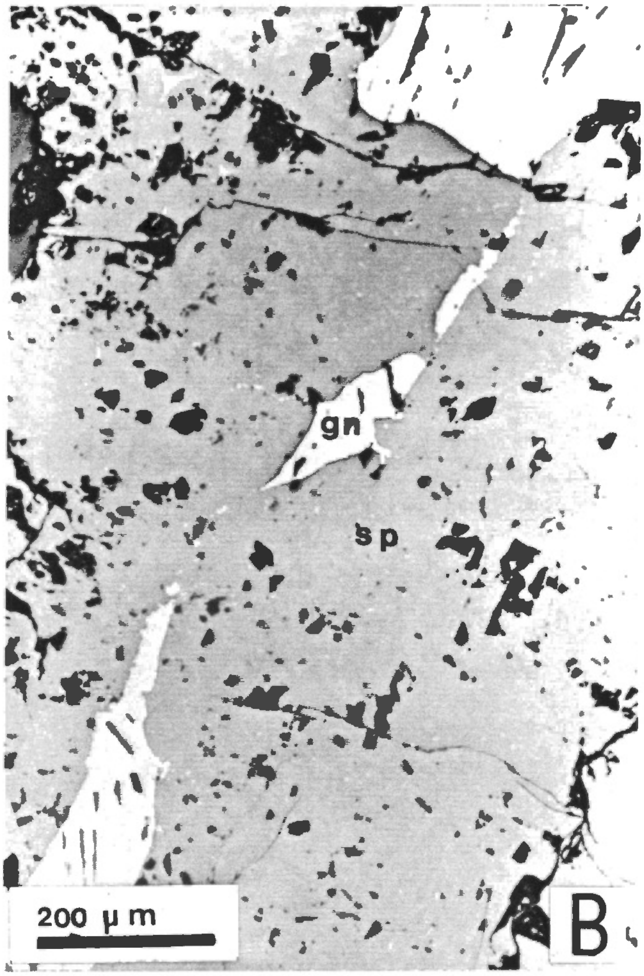


PLATE XVI 22H/4-2

Geological Survey of Canada
Open File 1495

METALLOGENIC STUDIES OF PB-ZN-BA OCCURRENCES IN THE LOWER AND MIDDLE PALEOZOIC SEDIMENTARY ROCKS OF THE LOWER ST-LAWRENCE AND NORTHERN GASPESIE AREA, QUEBEC

PART II

by

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Contribution to the "Plan de développement économique
Canada/Gaspésie et Bas Saint-Laurent
Volet Mines 1983-1988"

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ABSTRACT

Galena and/or sphalerite are the dominant sulfides in eight joint-, fracture-, breccia- and fault-bound mineral occurrences in the Paleozoic sedimentary sequence of the Lower St-Lawrence and northern Gaspésie area. One fault-bound occurrence in the southeastern part of Gaspésie contains abundant pyrite and arsenopyrite. Dominant gangue minerals are barite in two occurrences, quartz in two others (including the pyrite-arsenopyrite-rich one), and calcite with or without dolomite or siderite in the remainder. Field study and microscopy of these diverse occurrences show that they are essentially post-kinematic with respect to the latest brittle-deformation history of their contiguous host rocks.

Disseminated galena with or without sphalerite is the dominant sulfide in five mineral occurrences in the area. Four of these are hosted in sandstones and/or conglomerates; three are definitely stratabound. A minor occurrence is hosted in limestone. Sulfides and several (up to 5) translucent mineral species are cementing substances in all four sandstone-conglomerate hosted occurrences. Field study and microscopy of these diverse (!) occurrences suggest that they are pre-kinematic with respect to the earliest ductile deformation of their local host rocks.

Parts of the paragenetic sequence of gangue-gangue, sulfide-sulfide and gangue-sulfide have been tentatively deduced for individual occurrences or groups of several contiguous occurrences. However, no general paragenetic sequence is evident embracing sulfides and (1) gangue minerals in the vein-bound occurrences, and (2) other cementing mineral species in the disseminated occurrences.

TABLE OF CONTENTS: PART II

TABLES

FIGURES*

PLATES*

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*Legends are provided on pages designed to be facing figures and plates.

INTRODUCTION

Part II of this report is mainly concerned with the petrography of fourteen mineral occurrences studied and sampled by a field party of INRS-Géoressources in the summers of 1984 and 1985, under contract with the Government of Canada.

All available samples of the fourteen occurrences described in this report were inspected and the "best" selected for the preparation of thin sections[1]. Table 1 shows, among others, the numbering system of the sections studied; for instance 21N/5-1C-2 stands for the second section of sample C from occurrence 21N/5-1.

In the text we shall briefly describe the gross habit of a given occurrence, commonly illustrated with a field sketch; this will be followed by the petrography, while repeating as little as possible the documentation contained in figures, plates and captions, as well as that in Tables 2 and 3.

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[1]The selected hand specimens were slabbed; the slabs inspected; the "best" areas of the slabs cut out for the preparation of doubly polished thin sections. Care was taken, in the mounting of the blocks cut out, not to exceed a temperature of 50°C. Most sections are thus accompanied by a "witness" block, about ½ cm thick, covering the same area as the section.

OCCURRENCE 21N/5-1

About 5 km southeast of the village of St-Bruno, a pit, a small trench, and a major trench (29 x 1 m surface area) are all that remain from previous exploration work. The major trench is flooded with at least 1 m of water and prevents observation of field relations. All vein material collected is from blasted blocks next to this trench. The attitude of the major joint set in nearby sandstones (150°/vertical) is parallel to the trench walls and presumably to the vein(s).

The host rock is a medium-grained, slightly foliated quartzo-feldspathic sandstone. Vein material consists of medium- to very coarse-grained, massive barite, calcite, galena, minor quartz and enclaves of sandstone. Galena crystals are up to 2 cm in diameter. Thin barite veinlets in blocks of sandstone show a poorly developed comb structure and a minor porosity ($<$ 5% of mm-sized pores).

Microscopy

Coarse barite and calcite crystals dominate the samples studied. Both minerals have a sharp, at most very slightly undulous, extinction, indicative of the virtual absence of post-crystalline deformation. Nonetheless, most interstices between them are filled with a "granulated" matrix of anhedral fragments of calcite, barite, very minor quartz and rare, anhedral galena (Plate ID).

Galena, the only sulfide present, occurs predominantly next to or partially enclosed in barite; it is never entirely surrounded by calcite only. Plate I (A, B, C) strongly suggests that galena precipitated later than barite, and probably later than calcite.

OCCURRENCE 22C/7-3

The occurrence is located near the village of St-Fabien, along the southern flank of a hill, about 900 m east of the location reported in "Fiche de gîte minéral no 22C/7-3" (MERQ, 1982). It consists of a single escarpment measuring 13,5 x 5 m developed along a joint or fault plane (90°/80°S) that shows slabs of a barite vein adhering to it (Fig. 1). The vein samples collected are from these slabs.

The host rock is a massive, coarse, polymictic conglomerate with about 55% poorly sorted, subangular to subrounded pebbles, boulders and blocks (up to 1 m in diameter), set in a sandy, calcitic matrix. The main barite vein is 5 cm thick and contains about 1% of galena in cubes up to 1 cm in diameter. Next to this vein, minor irregular barite veinlets are present, some of which also contain galena. "Disseminated" galena reported in the host rock is probably contained in or contiguous to these minor veinlets. Numerous barren calcite and calcite-quartz veinlets cut across the host rock, commonly parallel to two joint sets (90°/vertical and 160°/85°S). They have not been observed to cut barite veins.

Microscopy

Coarsely crystalline barite and sparry calcite are the most abundant constituents of the vein. They commonly have a strongly undulating extinction, unlike those of the occurrence described previously. Locally, barite contains small, perfectly euhedral quartz crystals. Moreover, detrital, well-rounded quartz grains of the host rock in contact with barite or sparry calcite have developed partially euhedral shapes (cf. Part I, Plate IB).

Galena occurs in irregular, anhedral grains, locally with strongly bent cleavage pits. Plate II shows a fairly common relation of galena and barite, suggesting that galena filled open spaces in a framework of prismatic barite crystals.

No paragenetic relations could be established between the various sulfide species and opaque oxides (Table 2) in the vein.

OCCURRENCE 22A/9-1

The mineralization (sphalerite) occurs in a deeply rubble-covered brecciated zone in the wall of a trench (13 x 1,5 x 1 m). Two other trenches are present but are barren (Fig. 2).

The host rock, poorly exposed, is a fairly homogeneous, well-bedded, fine-grained calcarenite. Numerous small, closely spaced, barren carbonate-filled joints (120°/85°S) are present in all trenches. Only the 1-m wide brecciated zone (345°/70°NE) contains sphalerite.

The zone consists of a chaotic mixture of angular, non-sorted limestone fragments cemented by white to buff sparry carbonates. Locally these carbonates form discontinuous veins subparallel to the zone. Sphalerite appears to be concentrated in host rock fragments rather than in spar.

Microscopy

Calcite[2] and saddle dolomite, approximately in the ratio 7:3, are the carbonate species in the mineralized zone. At least some of the sparry calcite is "dedolomite", being characterized by its highly cloudy nature (iron-oxide particles?), curving cleavages and wavy extinction, probably inherited from a dolomite precursor (Plate IIIA, B). An other type of sparry calcite is present as well; it is as clear as the saddle dolomite, has no curved cleavages and has a sharp extinction.

Sphalerite, in grains up to 1 mm in diameter, is flecked in various hues of yellow, light purplish and, rarely, bluish. It does not display a color zoning. The mineral does not show a preferred association

[2]Stained red with alizarine red S.

with any of the carbonate species; its occurrence in host-rock fragments is clearly shown in Plate IIID.

OCCURRENCE 22A/10-1

Exposure of this occurrence is provided by an outcrop stripped by bulldozer, showing three breccia zones, two of which are trenched (Fig. 3). The host rock is a fine-grained grey calcarenite with numerous silty carbonate interlayers, giving the rock a finely laminated appearance.

The breccia zones consist of an intricate mixture of unsorted, angular fragments of host rock in a sparry, locally vein-like, matrix. Abundant sphalerite is locally present in these zones but the mineralized portions are almost completely dug out, making it difficult to recognize and measure the attitude of mineralized veins. The best estimate of the attitude of the sphalerite-bearing portions in the trenches is 150°/85°SW. The small, non-trenched zone is about 25 cm wide, and consists of 10-30 cm long, roughly ellipsoidal sparry bodies, lined up parallel to a plane striking about SSE and dipping 80°W.

Most samples collected, whether or not in situ, are extremely weathered, porous and rusty; they contain large (up to 10 cm) patches of nearly massive sphalerite.

Microscopy

The single fairly fresh specimen amenable to study of gangue minerals shows that over 90% of the spar is calcite, the remainder being saddle dolomite. Three types of calcite are present: (1) clear calcite with sharp extinction; (2) cloudy calcite with wavy extinction; and (3) calcite transitional between types (1) and (2). At least types (2) and (3) are probably "dedolomites". Some dolomite crystals show bands of black opaque matter parallel to the crystal faces (cf. Part I, Plate X). This matter is probably a mixture of organic material and iron hydroxides, with or without iron oxides and marcasite.

Sphalerite is flecked in hues of yellow (dominant), purplish, and blue (rare); it is not zoned. Grain-to-grain contacts of sphalerite-calcite and sphalerite-dolomite are present. Calcite and dolomite veinlets as well as enclosures of dolomite occur in sphalerite aggregates. Rare chalcopyrite granules occur in spar and in sphalerite. Marcasite has been observed enclosed in spar, but not in sphalerite.

OCCURRENCE 22A/16-2

The occurrence, finally relocated after three days of search by two-, three- and five-men crews, is 1,7 km due north of the parking lot of Forillon Park at Fort Penouille.

A 30-year old bulldozed trench, 90 m long, has left virtually no outcrop in place. All but one of the mineralized samples are from blocks in and along the trench. Exposure of immediate host rock is strictly limited as well. It is a finely laminated, grey, sparsely fossiliferous, dolomitic calcarenite-calcilutite. The predominant set of joints (348°/70°E) contains mm-wide veinlets of carbonate, generally devoid of sulfides, although one of them contains a few cubes of galena.

The grab samples studied are breccias consisting of 60% angular enclaves of host rock, up to several centimeters in diameter, cemented by an irregular, slightly porous network and ill-defined patches of white and pinkish spar. Most or all galena occurs in this cement in the form of individual cubes up to 1 cm in diameter, or in clusters of cubes up to several centimeters in diameter.

Microscopy

Angular, semi-opaque host rock fragments, containing "sedimentary" pyrite and marcasite, are embedded in a carbonate-sulfide matrix of which a mere 10% of the spar is clear calcite and not indicative of "dedolomite". Moreover, thin (100-200 μm), clear calcite veinlets cut across both host-rock fragments and saddle dolomite; it is unlikely that this, the latest, generation of carbonate has a dolomite precursor.

The characteristic distribution of "dedolomite" is clearly shown in Plate IVB. A clear crystal of calcite in a dolomitic part of the spar network is shown in Plates IVA and VIIIA (cathodoluminoscope). Large zones and patches of black opaque matter occur within or associated with saddle dolomite. One of these zones, scanned by electron-microprobe does not contain any detectable elements; presumably it consists of organic matter. Plate IV (C, D), however, shows that apparently similar opaque zones may also consist of marcasite, iron-oxides and iron hydroxides.

Galena, by far the most abundant sulfide, shows grain-to-grain contacts with all other constituents of the specimens. Euhedral outlines of galena crystals may consist partly of galena and partly of an opaque, non-reflectant substance, similar to that reported as an alteration product of galena in Part I, Plates VI and VII. A scan by electron-probe microanalyzer reveals the presence of significant Pb but not of S; most likely the alteration product is a lead oxide or hydroxide.

OCCURRENCE 22A/16-5

The occurrence is exceptionally well exposed by a joint-bound cliff (10 x 10 m) rising from the beach of the northeastern shore of Baie de Gaspé (Fig. 4). The main face is parallel to non-filled joints, the attitude of which is 315°/55°NE; the other faces are controlled by calcite-filled joints, dipping from 80° to 63° ESE. One of these (28°/70° ESE), of slightly brecciated habit, is the residence site of virtually all galena, although the other joint-bound calcite veins are very similar to the mineralized vein (Plate V).

The host rock is a highly fossiliferous limestone (wackestone), the beds of which are 10 to 30 cm thick, commonly separated from each other by clay-rich laminae. They dip from 20° to 25° southwesterly.

The galena-bearing vein ranges in thickness from 5 to 10 cm and consists of sparry calcite prisms, 1 to 3 cm long, commonly oriented at right angles to the walls on either side of the vein, leaving a central open space at the center (cf. Part I, Fig. 9). A thin zone of fine-grained calcite, small clasts and small galena grains separates the body of the vein from the wall rock. Irregular enclaves of the host and galena cubes, both up to several centimeters in diameter, occur throughout the vein (Plate VB). The latter are well spaced and do not form agglomerations.

Microscopy

Plate VI illustrates some aspects of the mineralized vein. Cloudy sparry calcite contains numerous tiny fluid inclusions (< 5 µm) and has clear rims devoid of fluid inclusions. Pyrite and marcasite occur in trace amounts; dolomite, sphalerite and chalcopyrite are absent.

OCCURRENCE 22A/16-7

Wave-washed cliffs along the west shore of southern Forillon Peninsula offer excellent exposure to study sparry sphalerite-bearing veins and veinlets and their relation to brittle-deformation features of the host rock. This is presumably occurrence no. 22A/16-7 of the "fiche de gîte minéral" (MERQ, 1981), although the UMG coordinates differ and the fiche mentions galena as the only (major?) sulfide.

The host rock is a grey, fossiliferous, massive calcarenite with a well defined bedding (163°/27°W). The beds, 10 to 40 cm thick, are slightly undulating due to abundant colonies of bryozoa. Fine millimetric laminae of silty or clay-rich matter are present; one or two occur about every meter.

The rock is cut by numerous subparallel joints, all filled by spar and angular to tabular enclaves of the host rock. One of these, 20 cm wide, and a serie of similarly oriented (29°/72°SE) minor veinlets nearby are sphalerite-bearing (Fig. 5). The other main occurrence is in a slickensided, spar-filled fault (18°/55°E) that appears to converge with the mineralized joint; the point of convergence is, however, covered by overburden. A third, minor, occurrence of sphalerite is a 30-cm wide brecciated zone, parallel to joints nearby (35°/65°SE). Filled with coarse white calcite and enclaves of host rock, it contains a few crystals of sphalerite.

The mineralization, generally being less than 1 vol.% of the veins, consists of subhedral crystalline aggregates of sphalerite up to 2 cm in diameter, set in white, sparry calcite.

Microscopy

Study of a small sample of one of the minor sphalerite-bearing veinlets shown in the lower half of Fig. 5 offers an astonishing wealth of detail: see Plates VII and VIII (B, C, D).

A near-perfect symmetry is evident in the upper, comb-textured, dolomitic part of the veinlet (zones 1, 2 and 3 of Plate VII), the plane of symmetry being a zone discontinuously filled with sparry calcite and having minor open pores. Although the sparry calcite contains relatively large goethite (?) particles (Plate VIIID), it is fairly clear and has a sharp extinction, not typical of "dedolomite". Zone 4 consists of massive sparry calcite, some relatively small dolomite rhombs, and contains all sphalerite present in the specimen. It is highly unlikely that this calcite is a "dedolomite". Plate VIIIB shows in zone 1 lamellae of "dedolomite" in a dolomitic matrix; these lamellae are curiously oriented at an acute angle to the vein selvedge. This oblique orientation is also visible in zones 3 and 5 (Plate VII). Plate VIIIC and D show details of the calcite-rich plane of symmetry. Very thin calcite stringers, elsewhere in the section, cut across the entire saddle-dolomite zone and locally extend into and across zone 3 to disappear in the calcite-sphalerite zone (they do not carry sphalerite).

These stringers appear to be the latest generation of carbonate, and are definitely not "dedolomites". Tiny fluid inclusions (< 5 μm) are present in virtually all zones.

Based on this multiply zoned veinlet of about 10 mm wide, it is suggested that the oblique orientation visible in zones 1, 5 and the lower part of zone 3 formed during the opening of a joint in a direction different from that during the growth of zone 2 (rotation of the field of stress). The temporal relations of filling of the various zones, in particular of zones 2 and 4, cannot be deduced with certainty from this single section.

The zones defined above can be correlated with those of another veinlet studied from a similar location (lower half of Fig. 5). The specimen does, however, show pores without calcite as its plane of symmetry in the zone of saddle dolomite.

OCCURRENCE 22H/4-4

Three zones in rapids and a small waterfall of the Rivière-à-Pierre (or Rivière Mont St-Pierre) contain one or more sulfide-bearing quartz and quartz-carbonate veins (Figs. 6, 7) in a slaty host rock.

More precisely, the host rock is a dark grey to blackish shale to sandy siltstone with a well developed cleavage subparallel to bedding

(275°/5°N). It consists of ~ 60% phyllosilicates and contains 10-20% of spherical to elliptical zones, 1 to 10 mm in diameter, rich in quartz and pyrite. Generally highly weathered, it is exposed mainly in huge, joint-controlled blocks along the river bank. The predominant joint set strikes W to WNW and dips 80°-90°N. Except for the bedding-parallel vein in zone II, the mineralized veins are parallel to these joints.

The main vein in zone I (270°/80°N), the zone richest in sulfides, is about 10-20 cm wide and consists of large quartz prisms, up to 10 cm long, and "rusty" sparry dolomite or siderite. The ratio quartz:carbonate is about 4:1. The quartz prisms are aligned both perpendicular and parallel to the vein selvedge so that the vein does not have the marked comb structure shown in Schrijver, 1985, Fig. 12. Nonetheless, vugs are present in the central part of the vein, where also most pyrite occurs. Small quartz crystals (~ 2 mm) line many of the vugs. The sulfides, in decreasing order of abundance, are pyrite, galena and sphalerite. Euhedral pyrite cubes, up to 5 mm in rib length, are clustered in lenses up to 10 cm long, parallel to the vein walls. Galena and sphalerite, in stringers of up to 1 cm wide and 5 cm long tend to occur contiguous to the walls.

The single vein of zone II is relatively well exposed in the river bed; it follows bedding and schistosity (275°/5°N). Ranging in width from 5 to 10 cm, it is relatively poor in the three sulfides (same order of abundance as in I). Contrary to zone I, pyrite tends to be concentrated along the vein margins and in contiguous host rock, while galena and sphalerite tend to be closely associated with the gangue carbonate. In other respects, the fabric of the vein is similar to that in zone I.

In zone III, a single vein up to 5 cm wide (300°/80°N) is essentially similar to the zone-I vein, but it is not as coarsely crystalline and has a diffuse banding parallel to the vein selvedges, made more conspicuous by the alignment of vugs, semi-centrally located pyrite lenses, and the distribution of relatively sparse galena and sphalerite along the vein walls. The only gangue mineral in this vein is quartz. In particular, the weathered surface of the vein suggests episodic filling of an opening joint, with perhaps three consecutive layers.

Microscopy

One specimen of the main vein of zone I, and two of the relatively fine-grained, banded vein of zone III were selected for microscopic work. The latter two encompass the entire vein width.

Plate IXA and B illustrate the fairly common intergrowth of subhedral to anhedral crystals of galena and euhedral pyrite. The mantling of galena by pyrite (Plate IXA) strongly suggests early precipitation of galena (inclusions of pyrite in galena are extremely rare). The paragenetic relations of sphalerite with other sulfides are not evident.

Non-zoned, yellow to orange and brown sphalerite invariably contain tiny grains (~ 6 µm) of chalcopyrite. The latter mineral rarely occurs independent of sphalerite. Galena is most abundantly present in the form of large subhedral crystals, locally "molded" on euhedral quartz prisms; it occurs as well in minute grains enclosed in quartz (cf. Part I, Plate XVA, D) and in interstices between quartz grains. These interstices strongly resemble the vugs shows in Plate IXC. Pyrite, on the other hand, does not seem to be a common vug-filling mineral, because its form is typically cubic, unlike the erratically angular vugs.

A few subhedral crystals (0,5 mm in diameter) of pyrrhotite are present in the sample from the zone-I vein.

OCCURRENCE 22A/6-1

The showing, remote and quite different from all other occurrences mapped (including the 22H/4 veins), is about 30 km northwest of Port-Daniel on Baie des Chaleurs. A bulldozed track leads to a trench in which the "filon Baker" occurs. The vein is a locally heavily mineralized, anastomosing body of quartz and fragments of host rock, discontinuously exposed for 30 m (20°/80°-90°E) with a width of 0,5 to 1 m. One-hundred meters east-northeast along the same track occurs the "filon Mercereau", deeply covered in rubble. The vein has not been observed, but a dump of barren quartzose fragments is present next to it. Extensive exploration work has been carried out in this vicinity, including the drilling of 35 holes by Esso Ressources Canada (1974-1978). At least one of these holes has intersected the filon Baker (Fiche de gîte minéral no. 22A/6-1, MERQ, 1982), but only parts of the logs are available; they are extremely cursory.

The host rock, poorly exposed, is a sequence of medium-to fine-grained greywackes with minor dark grey layers and clasts of shale. Attitudes of bedding and cleavage are 250°/70°N and 255°/85°N respectively. One poorly developed set of joints is present (80°/75°S), locally filled by barren quartz.

Sulfides are restricted to the "Baker" vein consisting of quartz without carbonates, emplaced in an irregular <u>fault</u> zone: (1) the vein walls are not smooth and planar but are steplike and jagged; (2) the vein locally splits in two parallel zones; (3) in places almost half of the vein volume is brecciated host rock. The gangue is massive and fractures conchoidally; few well developed euhedral quartz prisms are present. Bands of massive sulfides, parallel to the vein walls, have fairly sharp contacts with the quartz gangue (Plate X). Minor sulfides also occur in centimeter-size blebs, vaguely aligned along cracks in the vein.

Microscopy

The characteristic mineralization in the specimen of Plate X consists of a thin layer of arsenopyrite in contact with quartz, followed by an ill-defined zone in which quartz, pyrite and arsenopyrite are tightly intergrown. The main mass of sulfides, on the right-hand side of the specimen, consists of a large (3 x 2 cm), anhedral, poikilitic crystal of galena, enclosing and tightly intergrown with pyrite, minor arsenopyrite and subordinate sphalerite. Chalcopyrite is present only within sphalerite grains. The overall textural relations, too coarse to be shown in photomicrographs, suggest late precipitation of galena with respect to that of the other sulfides.

The crack-bound sulfides are arsenopyrite and arsenopyrite-pyrite intergrowths.

OCCURRENCE 21N/15-1

Hard to find in a plowed and level farmed field, this occurrence of sandstone-hosted, disseminated sulfides is exposed in two small (60 cm diameter), fairly fresh outcrops, about 2 m from each other. A small gossan-like outcrop is present as well in a nearby furrow. Both fresh outcrops are heavily mineralized (~ 40% sulfides), one dominantly by pyrite, the other mostly by galena. A gravel pit, now filled and levelled, was the original site of discovery according to "Fiche de gîte minéral no. 21N/15-1" (MERQ, 1982). Preciously little first-hand field evidence is available. The specimens collected are faintly banded by the distribution of sulfides and contain a few clasts of shale, less than 1 cm in diameter.

In 1982, Labrador Mining drilled eight holes, seven vertical and one inclined, ranging in depth from 15 to 46 m, all in the vicinity of the occurrence (one hole collared in the outcrop rich in galena). All core has been destroyed or was lost (Y. Bruneau, pers. comm., September 1985), but full logs with assay values were kindly sent to us by the company (now part of Norcen Energy). Based essentially on the logs and Lespérance and Grenier's (1969) field work, Fig. 8 shows a rough, tentative cross-section of the occurrence. The stratabound nature of the sulfides is more than likely. They form a zone about 3,5 m thick of which the lateral extention is poorly known (at least 100 m^2). To the degree that the inferred directions of movement along the set of faults in Fig. 8 are correct, it would seem that the eventual eastern extension is truncated by the present level of erosion. The western extension would be progressively deeper but would probably not traverse the unconformity on top of the Cambro-Ordovician sequence. A rough vertical sulfide zoning may be present from pyrite at the base to sphalerite followed by galena at the top; this is however not confirmed by assay values from scattered and grossly discontinuous core intervals. Laterally, a Pb-Zn-bearing zone seems to grade into a pyritiferous zone, followed by barren sandstone. No estimates of tonnage and grade can be given from the available information.

Microscopy

Plate XIA shows the characteristic texture of the galena-rich sample. Quartz and feldspar form detrital components, whereas epitactic quartz and sulfides form cement. Epitaxy is particularly clear in the not uncommon case that the detrital interior of the quartz grain is cloudy (rich in fluid inclusions) and the overgrowth is clear (poor in fluid inclusions): see Plate XIB. Feldspar, both plagioclase and K-feldspar, are slightly to strongly altered into sericite and/or carbonate; no epitactic rims on feldspar are evident.

The paragenetic relations of the sulfide species are indefinite. Where galena-sphalerite grain-to-grain contacts are present, the latter mineral may fill the center of the interstice, mantled by galena (Plate XI, C, D). Equally common is the presence of small, anhedral galena grains surrounded by subhedral sphalerite crystals. Subordinate chalcopyrite and rare pyrite are invariably intergrown with, or enclosed in, galena or sphalerite.

The pyrite-rich sample contains quartz, feldspars, pyrite and traces of chalcopyrite. Epitactic quartz is present, but is not as clearly visible as in the galena-rich specimen. Pyrite occurs in anhedral to subhedral grains in sizes up to those of the detrital grains. Euhedral pyrite is present as relatively small crystals, locally enclosed in felsic minerals.

OCCURRENCE 22C/2-1

Near the locality indicated on the "Fiche de gîte minéral no. 22C/2-1" (MERQ, 1981), a lumber road exposes the contact between a highly fossiliferous, grey limestone and a sandstone. The contact (bedding) strikes NNE and dips 45° WSW. A poorly developed fissility is present, subparallel to bedding. No joints, faults or veins have been observed.

A thorough search revealed a few cubes of galena in the limestone, not preferentially associated with any of the constituents or textures of the rock. The local sandstone is barren.

OCCURRENCE 22C/7-4

Previously described for its barite (-sulfide) veins (Part I, pp. 11-13; Figs. 3-4), the present description centers on the disseminated sulfides (mainly galena) exposed particularly well in the adit of the St-Fabien "barite mine".

In the summer of 1984, it was pointed out to us by D.F. Sangster (Geological Survey of Canada) that galena-bearing sandstones were present in the muckpile outside the adit, confirmed by us during a brief revisit. In 1985, initially aided by Mr. Bertrand Ross of Rimouski, owner of the mining rights, a search was made for similarly mineralized bedrock on the steep hill above the adit and in the adit. It proved that considerable disseminated galena is present in the local sandstone and, in minor quantities, in the local calcareous conglomerate that hosts most of the vein-bound barite. Professional washing down of the underground workings by the "pompiers" of the St-Fabien fire department (Le Rimouskois, 29 October and 12 November, 1985) made clear that detailed mapping of the adit would be necessary to unravel the seemingly complex distribution of barite and galena, both in veins and veinlets, and in strictly disseminated form. The maps showing this work, by our student Georges Beaudoin, were sent to our G.S.C. liaison agent D.F. Sangster; they show among others the specimen locations of a total of more than 40 samples.

Clearly, a more complete report would be in order, incorporating our 1986 work. In summary: a sequence of interlayered polymictic calcareous conglomerates, sandstones (locally laminated and faintly graded) and shales is folded, faulted and jointed with concomittant or episodic filling of openings by networks of barite, carbonates and sulfides. Filling of interstices in the sandstones and rarely (?) in the conglomerates by sulfides undoubtedly preceeded emplacement of all or most veins, but the sequence of events and their precise temporal evolution are not obvious.

Microscopy

Plates XII and XIII illustrate the various modes of occurrence of galena in a sandstone from an unknown location in the adit (fresh specimen found on the dump containing ~ 10% galena). The light grey massive rock consists of detrital quartz and feldspar, 10% of angular shaly clasts up to 1 cm in diameter, and small (< 5 mm) phosphate nodules. Epitactic quartz, galena, minor carbonates and chlorite constitute cement. The carbonate is mainly dolomite, locally marginally or sectorially replaced by calcite. Cement-like galena is indeed most abundant (Plate XII); in addition, some detrital grains of albite are partially replaced by galena (Plate XIIIA, B). Most surprisingly, a single anhedral galena grain is present in a phosphate nodule (Plate XIIIC, D). This grain suggests an early, possibly detrital, particle as it is surrounded by a colloform rim of phosphate, similar to several other rims around quartz and carbonate inclusions in the nodule. Subordinate pyrite and rare chalcopyrite are present; sphalerite is absent.

An other specimen studied is a finer-grained, massive grey sandstone with quartz and feldspar, both having a gliding extinction and showing numerous incipient microcracks. One face of the specimen is coated with coarse-grained barite and galena ("placage" on Beaudoin's map of the adit), in which originate several hair-fine barite-dolomite veinlets traversing the sandstone. Galena, although present as an interstitial mineral in the sandstone, is preferentially associated with, or contained in, these veinlets (Plate XIVC), in which it is locally replaced by dolomite (Plate XIVA). Carbonate outside of the veinlets, occurring as a cement, is calcite.

The corroded nature of the galena-calcite contact shown in Plate XIVB is from a specimen of a polymictic calcareous (calcitic) conglomerate with some disseminated galena. Although non-diagnostic by itself, and despite the common association of galena and coarse sparry calcite in this rock, the contact is tentatively interpreted as a replacement of galena by calcite on the basis of the relations shown in Plate XIVA. The specimen contains aggregates of coarsely crystalline pyrite as the latest sulfide species, enclosing relicts of galena grains.

Lastly, a massive fine-grained grey sandstone from the adit, without barite veinlets, contains barite as a major cement (Plate XIVD), that locally invades altered detrital feldspar. The specimen contains only a few tiny grains of galena.

OCCURRENCE 22C/8-1

In a trench (6 x 2 x 3,5 m), a ledge 3 m high and 5 m wide exposes a microconglomerate in contact with a sandstone (Fig. 9); the contact is probably a fault (~ 8°/61°E). Between this contact and an exposed fault-plane in the microconglomerate (360°/70°E), several percent of disseminated galena occur. Numerous fine (1-5 mm) quartz veinlets are present, with attitudes ranging from 350° to 360° in strike and 70° to 80°E in dip. Where these veinlets are most abundant, most galena seems to occur, although they rarely contain any sulfide themselves.

The host rock is a very coarse sandstone or, rather, a microconglomerate consisting of well-rounded, moderately sorted quartz grains up to 5 mm in diameter, and 5-10% subrounded clasts of siliceous shale, set in a siliceous chloritic matrix. Bedding is poorly defined; its approximate attitude is 240°/80°N. The direction of displacement along the faults and subparallel quartz veinlets is indeterminate.

Galena occurs in cubes ranging in size from 1 to 10 mm, and in aggregates of cubes up to 5 cm in diameter. Other sulfides are pyrite (~ 1%), in nodules up to 3 mm in diameter, and subordinate chalcopyrite.

Microscopy

Detrital components are essentially quartz and feldspar. The former mineral is predominant; the occasional feldspar identified is equally rounded. Untwinned, non-altered feldspar may have been mistaken for quartz, so that the precise ratio quartz:feldspar is not known. Other detrital components are (1) relatively fine-grained clasts of sandstone; (2) very fine-grained, semi-opaque clasts of mudstone; (3) opaque organic matter; (4) unidentified opaque grains with sphalerite-like reflectance (a scan under the electron microprobe of several such grains shows Ti as the only element detected); (5) zircon and some other accessories. Interstices between the major detrital grains are relatively large, due in part to the large, extremely well-rounded form of the grains (see Plate XVC); they are filled with chlorite, subangular quartz grains of erratic shape, sulfides, and organic matter (locally rich in authigenic pyrite).

Plate XV (A, B) shows the characteristic mode of occurrence of galena, filling, together with chlorite, quartz and rare organic matter, the interstices between quartz grains. Plate XVD shows the corroded boundary of a detrital quartz grain in contact with interstitial chlorite. Clearly, the solution active in the formation of chlorite could, and at least locally did, dissolve quartz and replace it by chlorite. This may be the reason for the absence of epitactic quartz. Also, the noted angular, irregular form of small quartz grains in the interstices may be due, in part, to dissolution and replacement by chlorite. Moreover, minor features of corrosion of galena are evident locally, possibly being responsible for the disintegration of some major galena crystals and resulting in the formation of aggregates of small, anhedral galena grains (e.g. Plate XVA?).

Chalcopyrite occurs, as does galena, in the interstices between detrital grains, commonly but not invariably accompanied by, or enclosed in, galena. Only two small euhedral grains of sphalerite have been observed, both occurring in the fractured interior of a large detrital quartz grain.

OCCURRENCE 22B/9-1

The block of mineralized conglomerate initially sampled (1984), lying in the bed of the Cascapedia River, was revisited in 1985. It proved to be indeed bedrock fallen from the cliff rising from the riverbank, just above the summer-time water level. It is the only apparently non-explored sandstone-conglomerate hosted occurrence of disseminated sulfides among the four studied by us (Fiche de gîte minéral no. 22B/9-1, MERQ, undated). Also, it is quite different from the three described hereinbefore.

The outcrop forms a ledge less than 2 m high and about 200 m long. It exposes an interlayered assemblage of conglomerate and sandstone. One of the layers of conglomerate, about 0,5 m thick is mineralized, sulfides being concentrated in two ill defined zones, 2 cm thick and about 20 cm spaced apart, subparallel to bedding and alignment of clasts. The mineralized layer (Plate XVI) differs from other conglomerate layers by the abundance, type and rounding of the clasts. The sulfide-bearing layer consists of abundant, mainly well rounded, moderately sorted sandstone clasts with at most 25% sandstone matrix. The barren layers are made up of subrounded, poorly sorted clasts of mudstone, showing pronounced soft sediment deformation structures, and a considerable proportion (50%) of sandstone matrix. Sandstone layers are barren. The best estimate of the attitude of bedding is 85/10°S.

Two other exposures of similar conglomerate lenses are present nearby along the river bank. Both were carefully inspected: none appears to contain sulfides.

Macros- & microscopy

The sulfide-bearing layer is clast-supported, the clasts consisting of sandstones of a range of grainsizes and of fine- to very fine-grained sandy mudstones, set in a relatively coarse-grained sandstone matrix (Plate XVIIA, B). The matrix consists of subangular quartz and feldspar grains, chloritic grains (chloritized feldspars or mafic minerals?) as large as the quartz grains, and minor colorless phyllosilicates, all cemented by a network of carbonate of variable grain size (micrite, microsparite to frankly sparite). This carbonate cement is highly variable in abundance; roughly estimated it accounts for about 30 vol.% of the matrix. The distribution of carbonate species is quite irregular and variable but is very dominantly dolomite (average dolomite/calcite ratio $>$ 19/1). Carbonate species in the clasts are either predominantly calcite, or predominantly dolomite, or are as variable as in the sandstone matrix. Good evidence of dedolomitization exists, but is rare.

The sandstone layers (barren!) in the outcrop are virtually identical to the matrix of the conglomerate, e.g. carbonate is predominantly dolomite, but their grains are somewhat smaller.

Despite this similarity of barren sandstones and sandstone matrix, the sulfides in the mineralized conglomerate layer are without exception restricted to the matrix-filled spaces between the clasts. The preferred distribution of matrix-hosted sulfides is virtually impossible to show in a photomicrograph; it can only clearly been shown on the scale on an entire thin section (Plate XVIIC).

Sulfide aggregates, commonly discontinuously rimmed by dolomite rhombs of the sandstone matrix (Plate XVIIIA) consist, in decreasing order of abundance, of coarse galena, generally finer-grained marcasite and sphalerite, and minute grains of pyrite and rare chalcopyrite. Other opaque reflectant minerals are fairly coarse, anhedral shards of iron oxides and iron hydroxides, and granules with a sphalerite-like reflectance (only Ti was detected under the microprobe: cf. occurrence 22C/8-1).

This is the only occurrence in the study area in which sphalerite is ocasionally clearly color-zoned, most characteristic being a dark purplish center and a light yellow "overgrowth" (Plate XVIIIC, D).

The paragenetic sequence of the entire sulfide assemblage is not evident. Partial rims of marcasite around galena are a consistent feature (Plate XVIIIB). Incomplete rims of galena around sphalerite and vice versa, as well as enclosures of galena in sphalerite and vice versa, either suggest penecontemporaneous precipitation of these two sulfides or a sequence of multiple episodes of precipitation. The zoned sphalerite is a feature in favor of the latter alternative.

On the basis of the form and distribution of conglomerate lenses and the textures of the conglomerate-sandstone assemblage, the site of deposition of the sediments was probably the channel of a river, either strictly continental or marginally marine.

ACKNOWLEDGMENTS

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Table 1. Inventory of samples and sections[1]

1 OCCURRENCE #	2 G	3 COORDINATES (UMG)	4 N	5 n	6 (D)PT
21N/5-1	ba	5252600N - 447300E	5	C C	1 2
22C/7-3	ba	5345200N - 506030E	5	B D E	1 1 1
22A/9-1	ca	5398300N - 390500E	7	A A A C C	1 2 3 1 2
22A/10-1	ca	5394950N - 389200E	5	A B D	1 1 1
22A/16-2	ca	5413800N - 396200E	8	C E	1 1
22A/16-5	ca	5404350N - 410300E	6	A D	1 1
22A/16-7	ca	5402100N - 412200E	6	B B C	1 2 1
22H/4-4	q	5438950N - 289450E	11	D D F F H	1 2 1 2 1
22A/6-1	q	5360600N - 334900E	6	B B D	1 2 1
21N/15-1	x	5309300N - 518100E	4	A-1 B-1	1 1

Table 1 (continued)

1 OCCURRENCE #	2 G	3 COORDINATES (UMG)	4 N	5 n	6 (D)PT
22C/2-1	x	5327500N - 518950E	2	A B	1 1
22C/7-4	x	5347400N - 508600E	~38	L S T U	1 1 1 1
22C/8-1	x	5371250N - 562230E	7	F F G	1 2 1
22B/9-1	x	5402650N - 699600E	12	B B B E K K	1 2 3 1 1 2

[1]Column 1: No. "fiche de gîte" MERQ
Column 2: dominant gangue mineral: ba = barite; ca = carbonate; q = quartz; x = disseminated
Column 3: Universal Mercator Grid
Column 4: total number of samples available
Column 5: samples studied
Column 6: thin sections studied (microscopy; minor probe, X-ray)

Table 2. Vein-bound occurrences: constituents and relative abundances[1]

OCCURRENCE #	HOST ROCK[2]	MINERALOGY												
		GANGUE[3]					METALLIC AND SEMI-METALLICS[4]							
		ba	ca	do	q	p	py	ma	gn	sp	cp	Fe-O	Fe-O-H	OTHERS
21N/5-1	sst	●	○		x	x			●					
22C/7-3	co	●	○		x				●		x	x	x	
22A/9-1	ls		●	○		x	x			●				
22A/10-1	ls		●	○		?		x		●	x			
22A/16-2	ls/ds		○	●		x		x	●			x	x	Pb oxide?, O.M.
22A/16-5	ls		●			○	x	x	●					
22A/16-7	ls		●	●		x	x			●				
22H/4-4	sh			x	●	○	●		○	○	x		x	Pyrrhotite (rare)
22A/6-1	sst, sh				●	x	●		●	●	x			Arsenopyrite (abundant)

[1]As estimated from field, specimens and thin sections: ● = major; ○ = minor; x = trace

[2]co = conglomerate; ds = dolostone; ls = limestone; sh = shale; sst = sandstone.

[3]ba = barite; ca = calcite; do = dolomite or siderite; q = quartz; p = porosity.

[4]py = pyrite; ma = marcasite; gn = galena; sp = sphalerite; cp = chalcopyrite; Fe-O = iron oxide; Fe-O-H = iron hydroxide; O.M. = organic matter.

Table 3. Disseminated occurrences: constituents and relative abundances[1]

OCCURRENCE #	HOST ROCK[2]	TRANSLUCENT CEMENTS[3]						METALLIC AND SEMI-METALLICS[4]								
		ba	ca	do	q	chl	ep	py	ma	gn	sp	cp	Fe-O	Fe-O-H	O.M.	Sulfide cement
21N/15-1	sst				●		x	●		●	○	x				✓
22C/2-1	ls		●	x						●					●	
22C/7-4	sst, co	x	○	○	●	x		○		●		x			?	✓
22C/8-1	sst, co				?	●		○		●	x	○			○	✓
22B/9-1	co, sst		x	●		?		x	○	●	○	x	○	x	○	✓

[1]As estimated from specimens and thin sections: ● = major; ○ = minor; x = trace

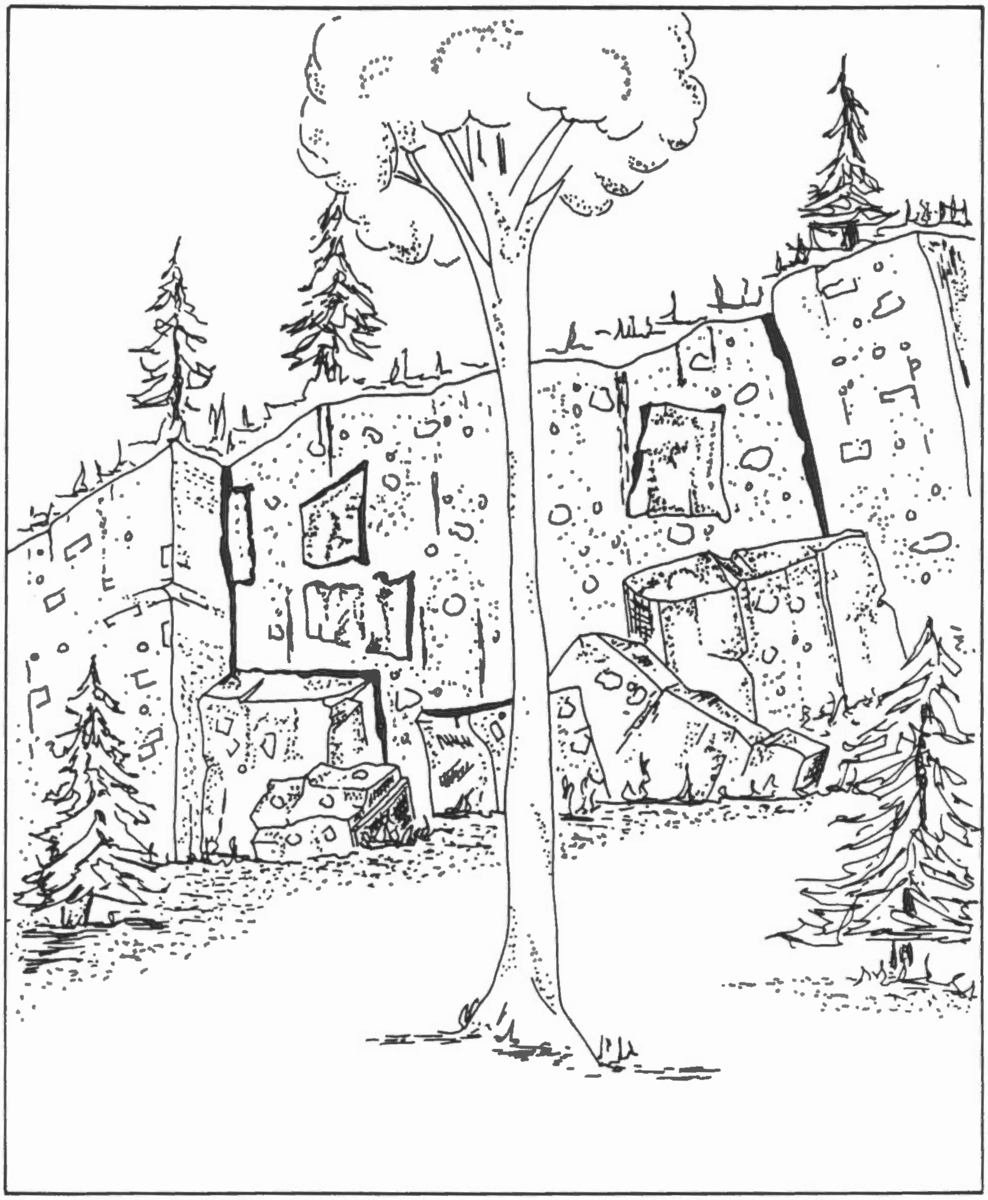
[2]co = conglomerate; ls = limestone; sst = sandstone.

[3]ba = barite; ca = calcite; do = dolomite or siderite; q = quartz; chl = chlorite; ep = epidote.

[4]py = pyrite; ma = marcasite; gn = galena; sp = sphalerite; cp = chalcopyrite; Fe-O = iron oxide; Fe-O-H = iron hydroxide; O.M. = organic matter.

FIGURE 1 - 22C/7-3

Barite vein (solid black) and calcite(-quartz) veinlets in coarse polymictic conglomerate.

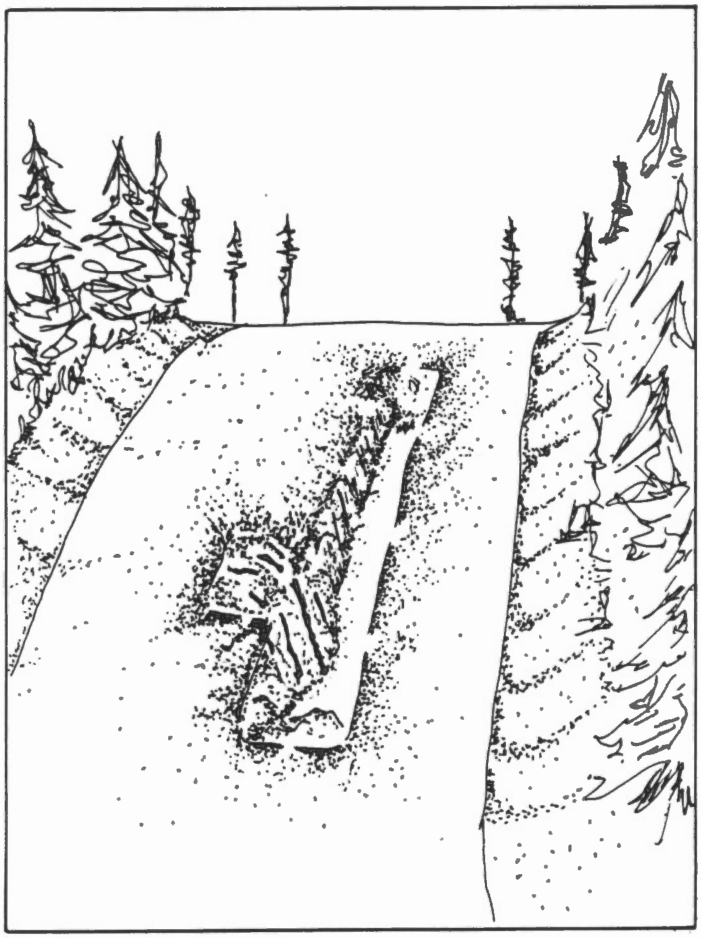


22 C/7-3

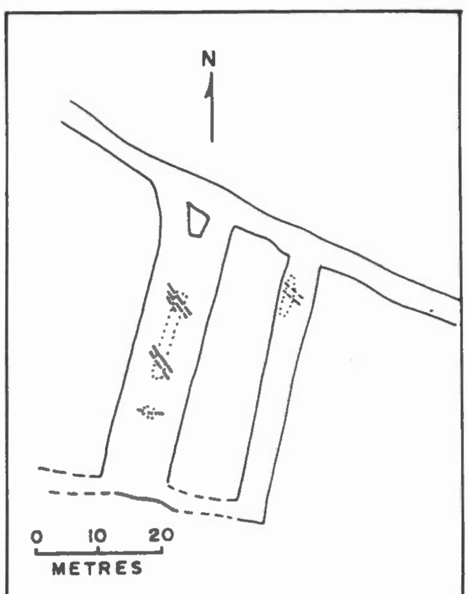
FIGURE 2 - 22A/9-1

Top: sphalerite-carbonate veins (solid black) in brecciated zone of calcarenite.

Bottom: only the central trench of the three trenches shown in the left-hand cleared zone (figure at top) contains sphalerite.



22 A/9-1

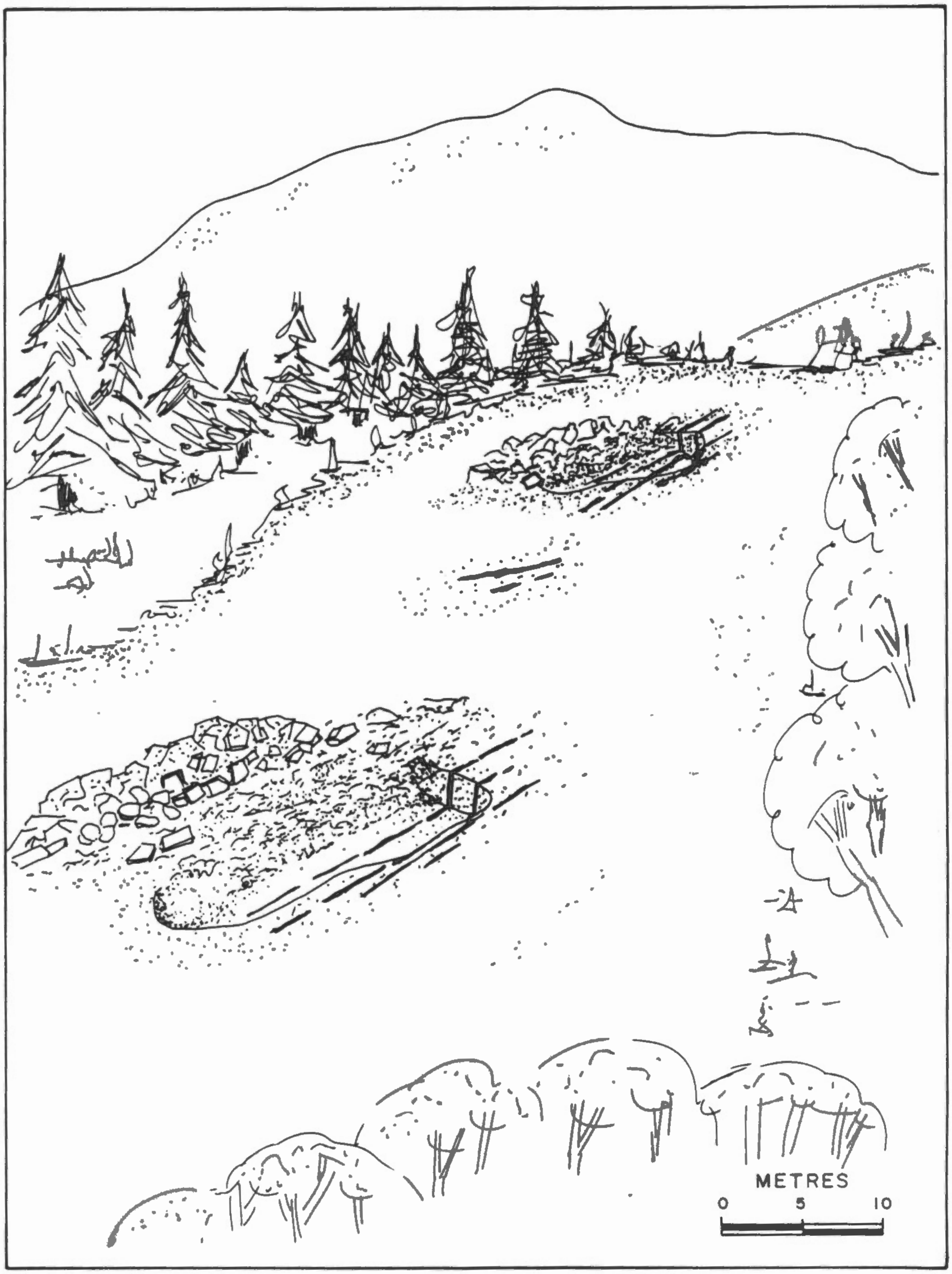


22 A/9-1

Fig. 2

FIGURE 3 - 22A/10-1

Exaggerated clearly defined sphalerite-carbonate veins (solid black) in three brecciated zones of calcarenite, two of which are trenched. Sketch facing East. Sample A is from rubble in topmost trench; B and D are in-situe samples from central zone; C is in-situe sample from lowermost trench.

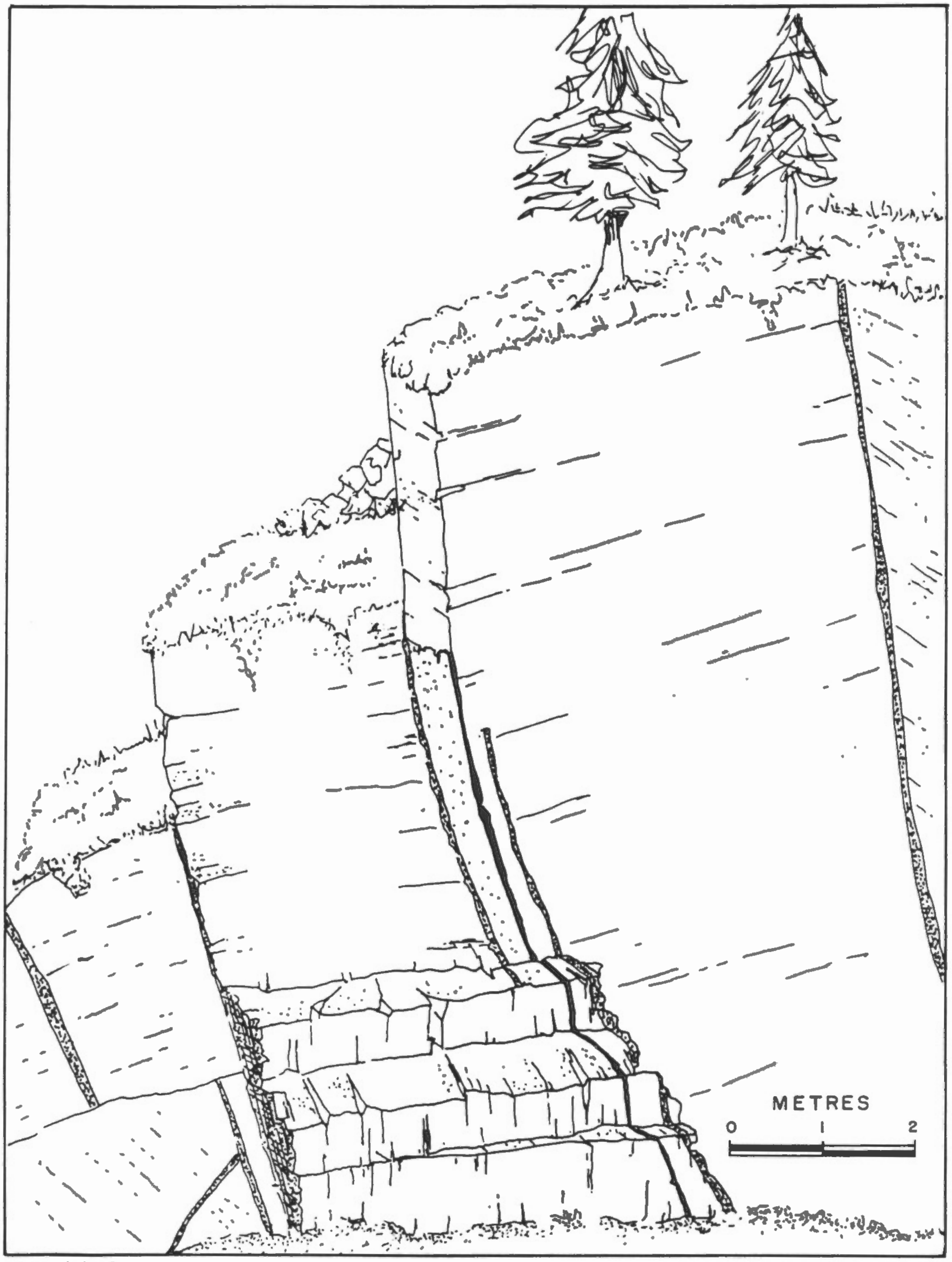


22 A/10-1

Г.3

FIGURE 4 - 22A/16-5

Well exposed galena-carbonate vein (solid black and dotted) subparallel to numerous carbonate-filled joints and tension gashes in well-bedded limestone. Face of cliff is parallel to tight (non-filled) joint set. Looking NE. See also Plate V.



22 A/16-5

FIGURE 5 - 22A/16-7

Top: main joint-bound and fault-bound sphalerite-carbonate veins (solid black, in center and right-hand side of figure respectively) in well-bedded limestone. Looking NNE.

Bottom: carbonate-filled tension cracks (solid black), most of which are sphalerite-bearing, subparallel to main joint-bound vein. Looking NE. Zoned veinlet of Plate VII (sample C) is from one of the lowermost tension cracks.

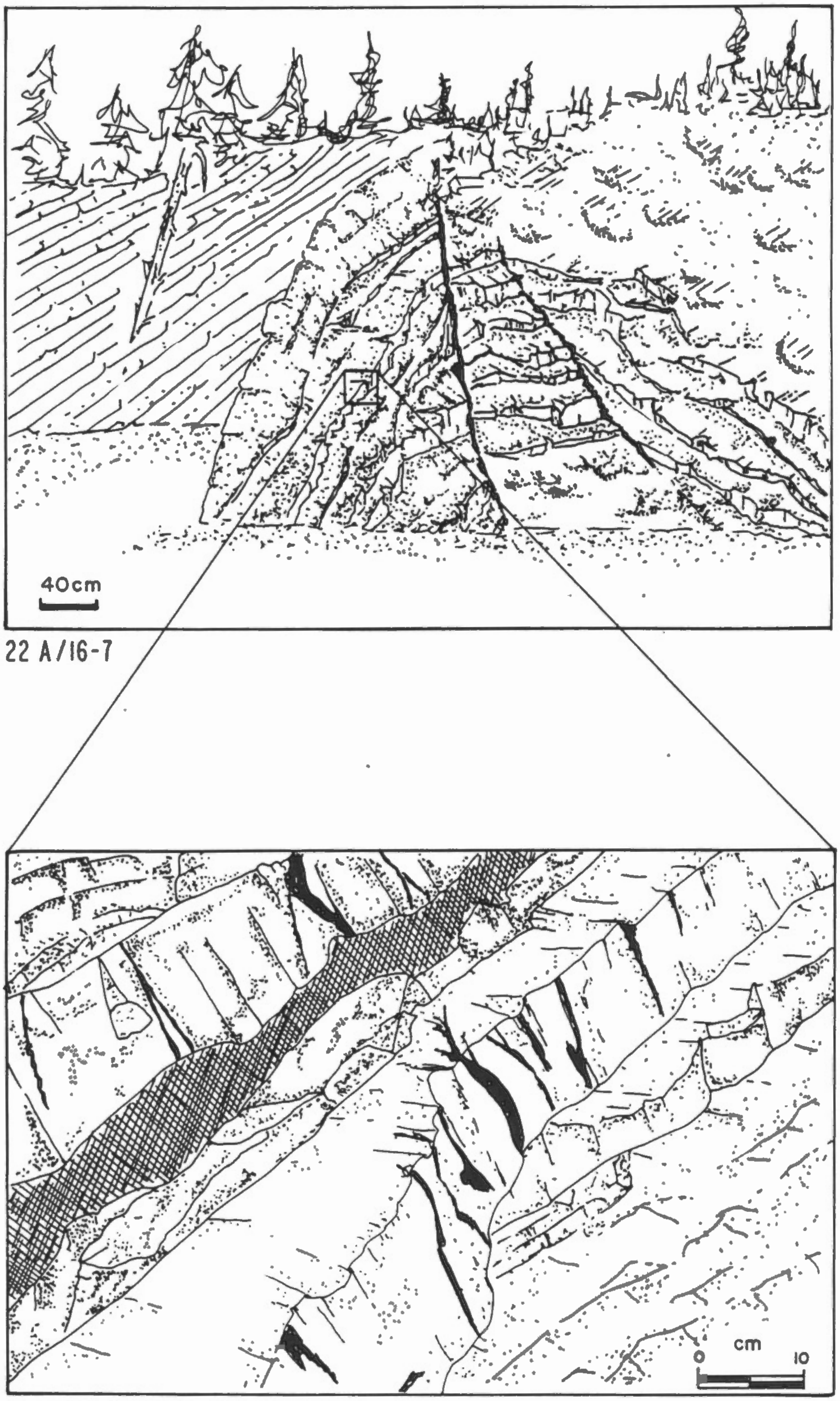
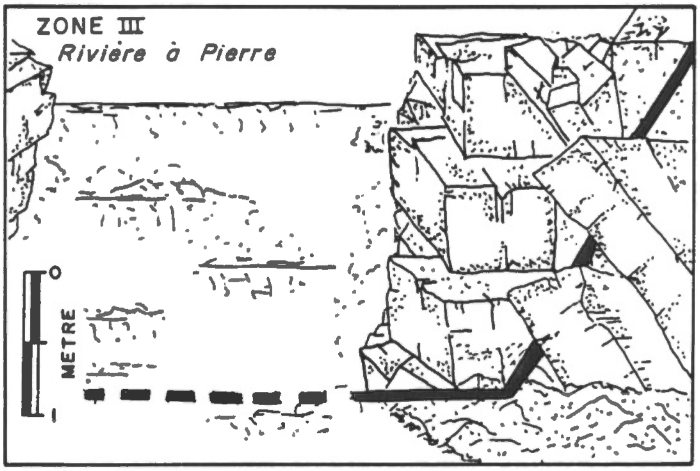

40cm
22 A/16-7
cm
0
10

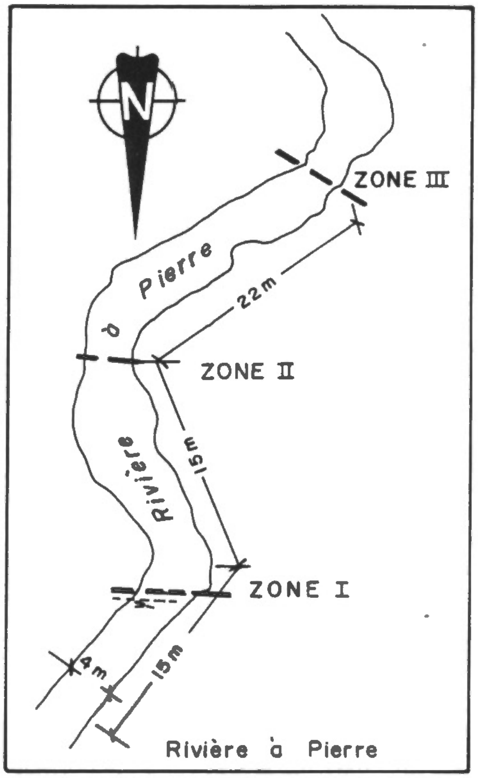
FIGURE 6 - 22H/4-4

Top: joint-bound sulphide-quartz vein (solid black) in shale of zone III. Samples E, F, G, H and K are from this vein.

Bottom: location map of the three mineralized zones.


ZONE III
Rivière à Pierre
METRE
0
1

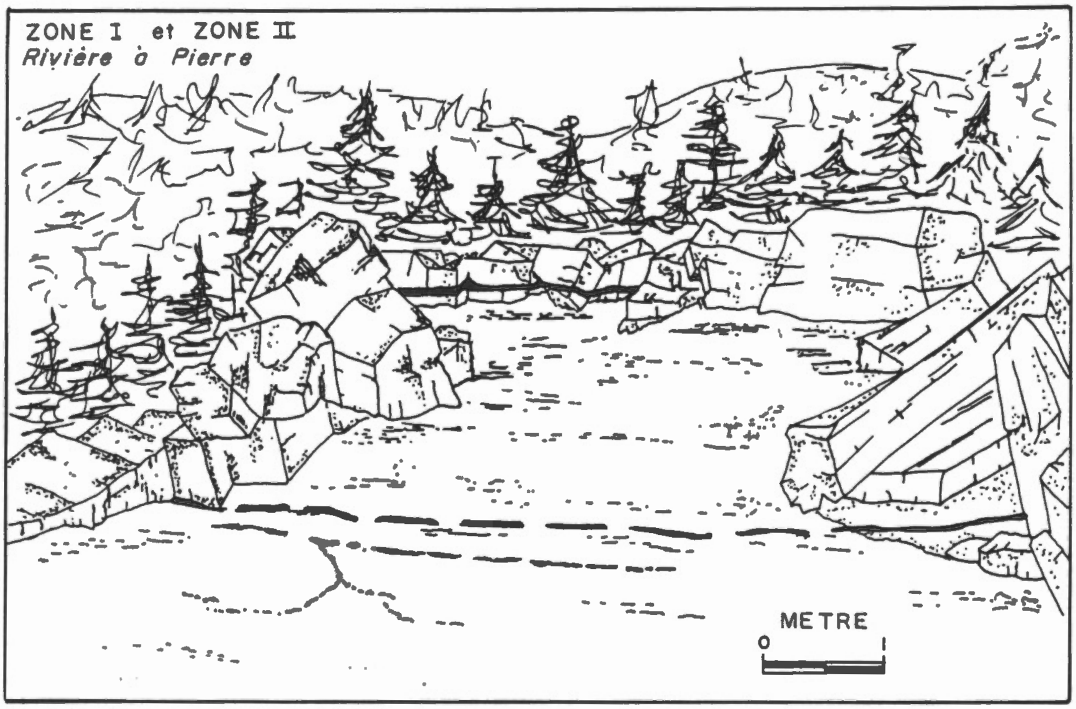
22 H/4-4


N
ZONE III
à Pierre
22m
ZONE II
Rivière
15m
ZONE I
4m
15m
Rivière à Pierre

22 H/4-4

FIGURE 7 - 22H/4-4

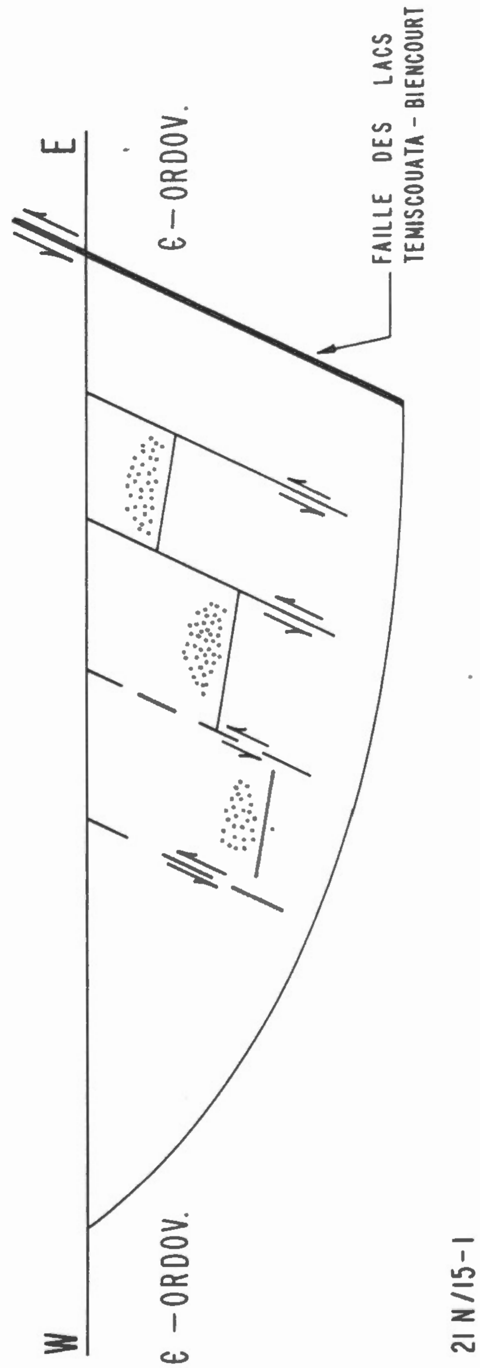
Sulphide-quartz veins (solid black) in shale. Cleavage/bedding-bound vein (zone II) is well exposed in river bed; samples I and J are from this vein. Samples A, B, C and D are from the major sulphide-rich, joint-bound vein of zone I.



22 H/4-4

FIGURE 8 - 21N/15-1

Rough, tentative E-W cross section based on logs of drill core and data from field. Not to scale. Stippled zones indicate distribution of disseminated sulphides. See discussion in text (pp. 121-122).



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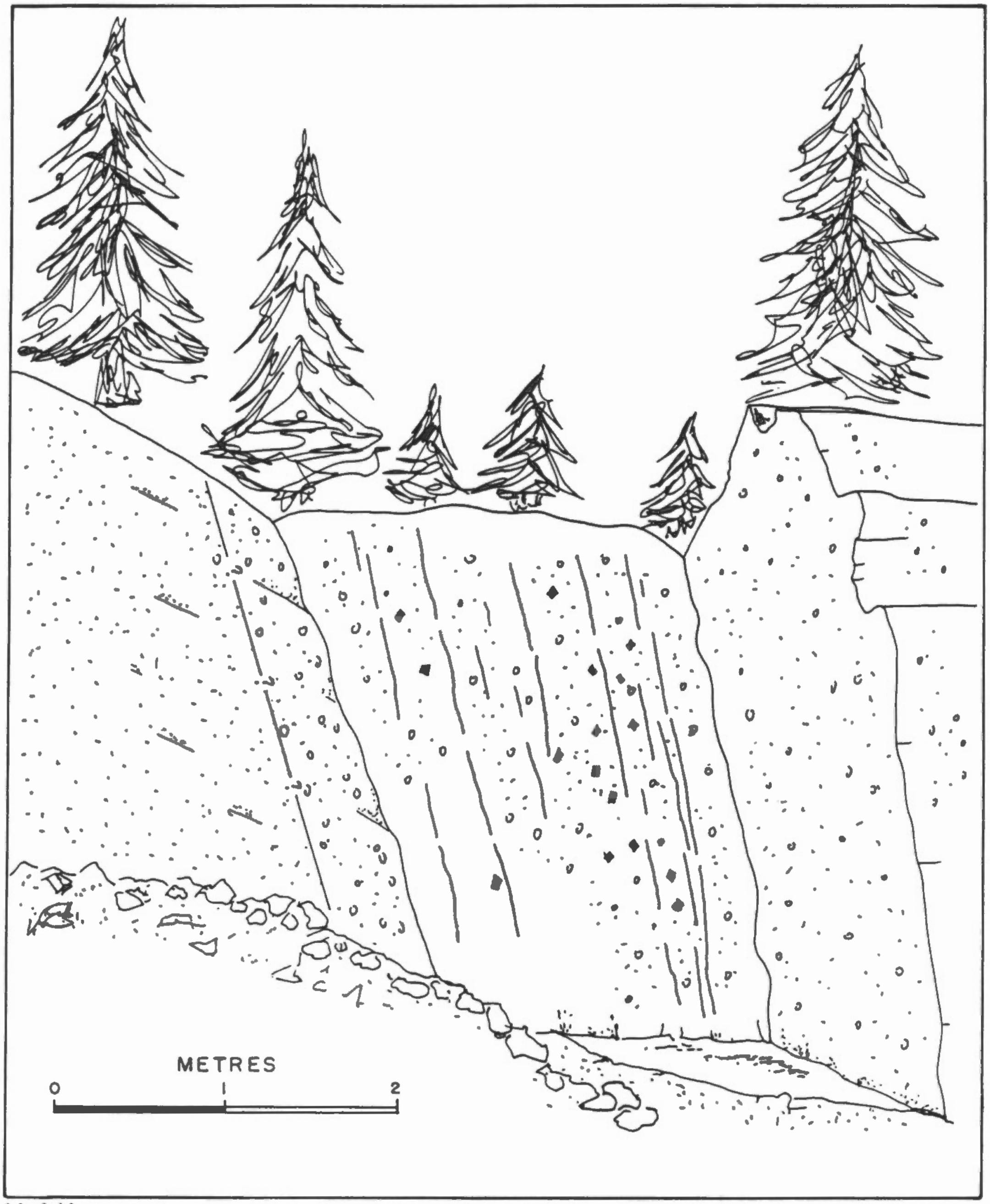
21 N/15-1

FIGURE 9 - 22C/8-1

Disseminated galena in microconglomerate. Note concentration of galena in part of exposure richest in quartz veinlets (lines). Probable fault contact between sandstone and microconglomerate is shown on left-hand side of figure. Looking North.



22 C/8-1

PLATE I - 21N/5-1

Photomicrographs of specimen C. A. Galena filling interstice between three barite crystals; plane-polarized light. B. As A, reflected light. C. Galena interpenetrating barite along cleavage plane. D. Interstice between major barite (white) and calcite (grey: stained) crystals filled with granulated barite, calcite and traces of quartz; plane-polarized light. This interstitial mortar texture is quite common (it may contain small anhedral galena grains), despite the fact that both major gangue minerals have at most a very minor undulous or gliding extinction.

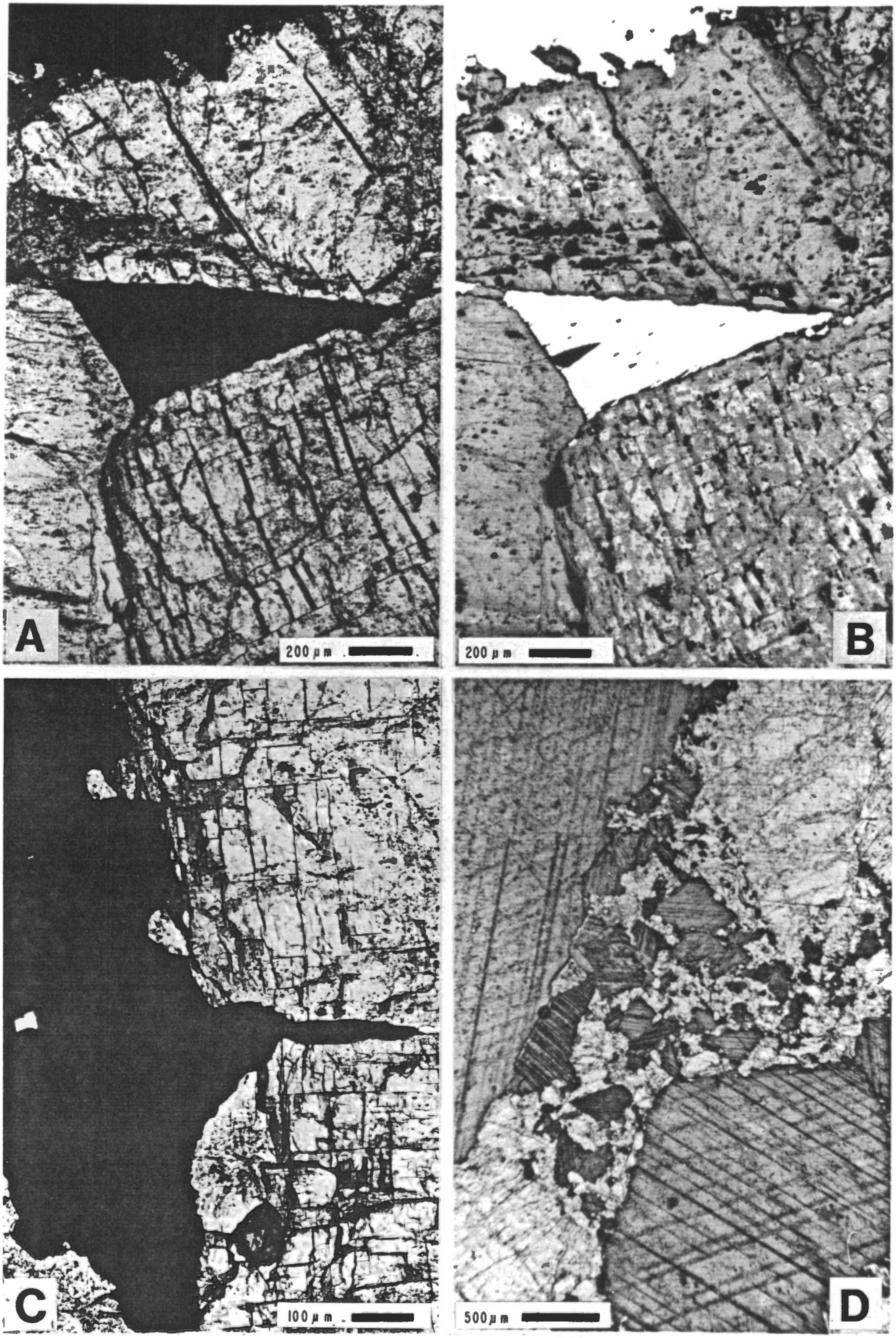


PLATE I : 21 N/5-1

PLATE II - 22C/7-3

Photomicrographs of specimen B. _A_. Anhedral galena grain filling interstice between euhedral barite prisms; plane-polarized light. _B_. As _A_ in reflected light. This texture, demonstrating that galena filled open spaces is a framework of barite prisms, is preserved despite the evidence of strain (strongly undulous extinction of barite and calcite; bent cleavages of galena).

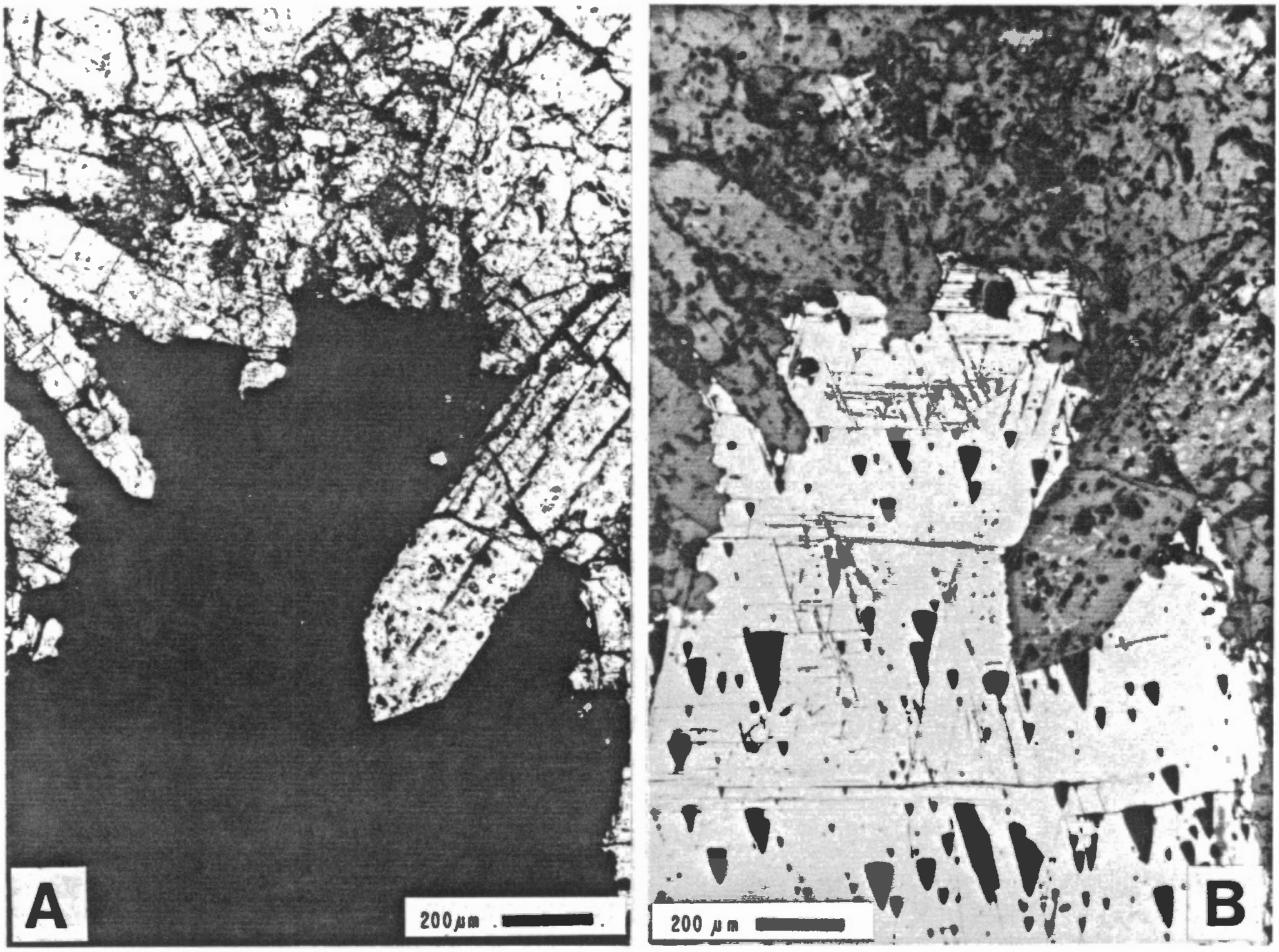


PLATE II : 22 C/7-3

PLATE III - 22A/9-1

Photomicrographs of specimen A (_A_, _B_, _C_) and specimen C (_D_). _A_. Saddle dolomite (white) and calcite (dark grey: stained) in contact with host rock fragment (black); plane-polarized light. _B_. Similar to _A_. _A_ and _B_ illustrate the characteristics of "dedolomite": in _A_ the dolomite cleavage above the major, cloudy calcite crystal is continuous with that below the calcite; in _B_, the curved cleavages (and undulous extinction) of the cloudy calcite suggest inheritance of these features from a dolomite precursor. The cloudiness of the dedolomite is probably due to unmixing of Fe^{2+} from precursor dolomite. _C_. Saddle dolomite veinlets (white) separate fragments of host rock (black) and contain euhedral crystals of sphalerite (grey; high relief); plane-polarized light. _D_. Host-rock fragment contains numerous euhedral sphalerite crystals (black), large calcite crystals (grey) and small dolomite grains (white); cross-polarized light.

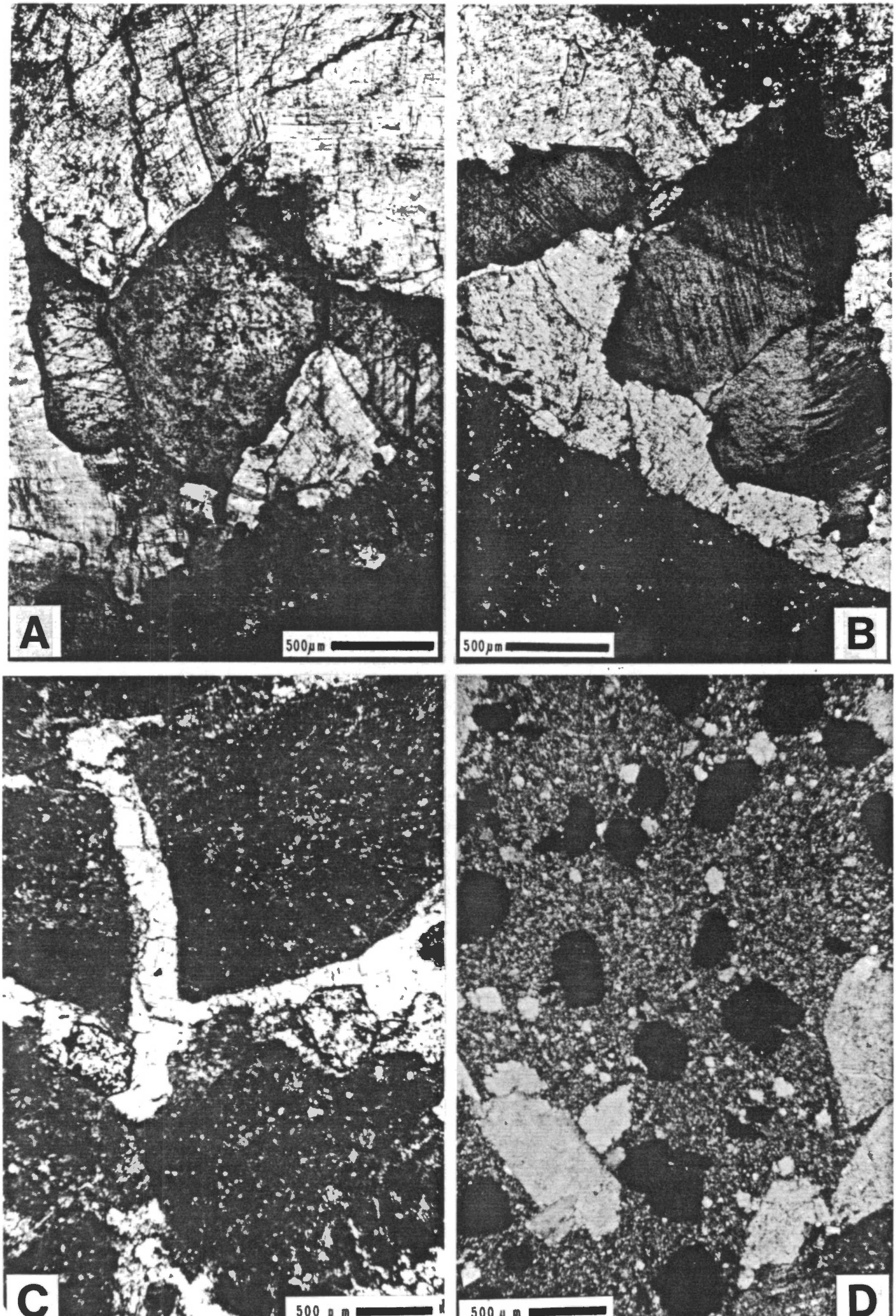


PLATE III : 22 A/9-1

PLATE IV - 22A/16-2

Photomicrographs of specimens C (A) and E (B, C, D). A. Clear calcite crystal (grey: stained) surrounded by saddle dolomite (white) and black, cryptocrystalline opaque, non-reflectant matter (probably a mixture of organic matter and iron hydroxides); plane-polarized light. See also Plate VIIIA. B. Saddle dolomite (white), partially replaced by calcite (dark grey: stained), with black cryptocrystalline body similar to matter in A; plane-polarized light. C. Cloudy dolomite with black veinlet; plane-polarized light. D. Same as C in reflected light. Clearly, not all black matter is similar; in this case it is not cryptocrystalline and consists of marcasite, iron oxide, iron hydroxide and, possibly, organic matter.

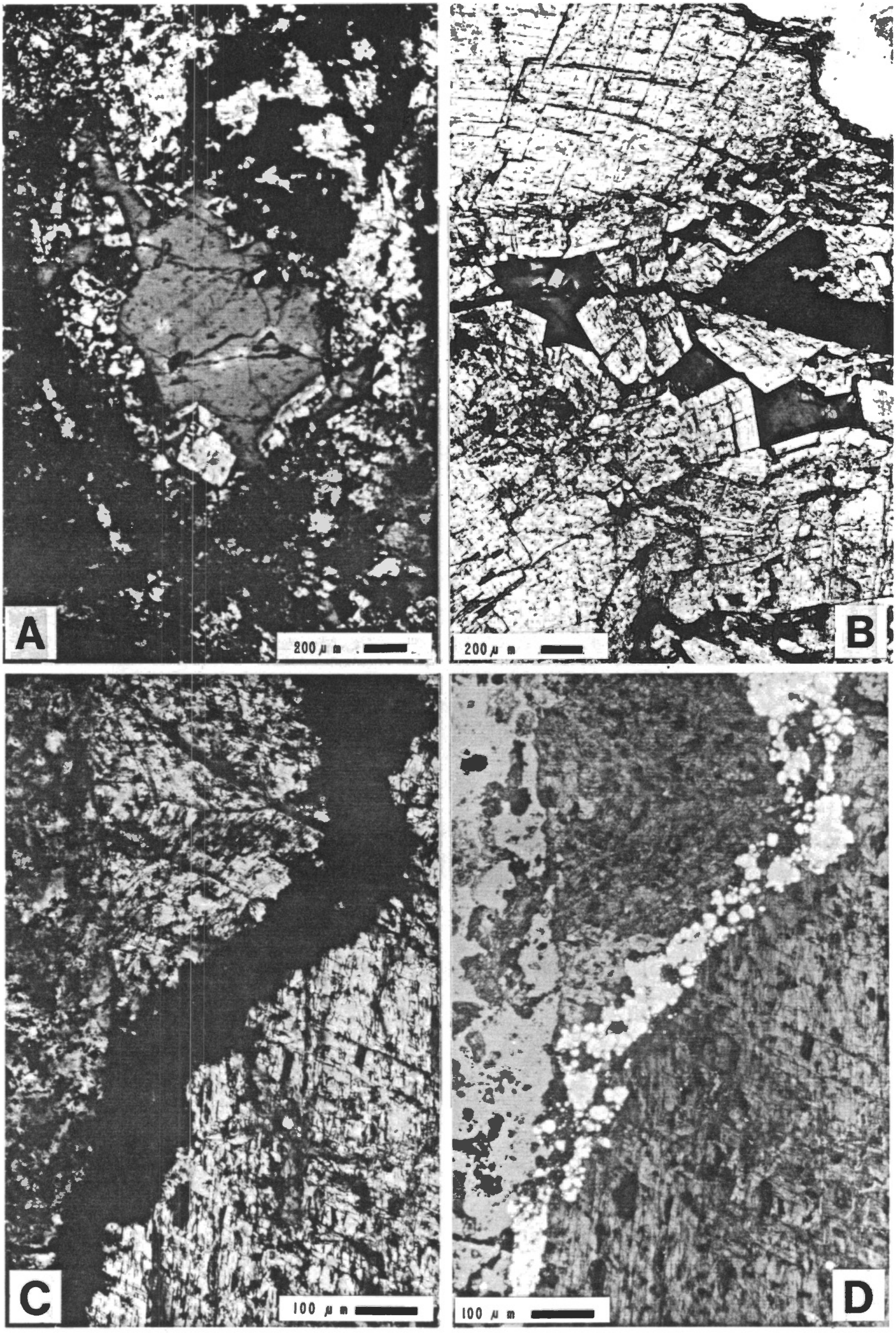


PLATE IV : 22 A/16-2

PLATE V - 22A/16-5

A. Set of subparallel carbonate veins, the widest, anastomosing of which is the residence site of virtually all galena in this occurrence. See also Fig. 4. B. Polished slab of one half of this vein and host rock showing two major galena crystals (black at top; black and slightly reflectant further down) and several fragments of host (grey) in calcite (white).

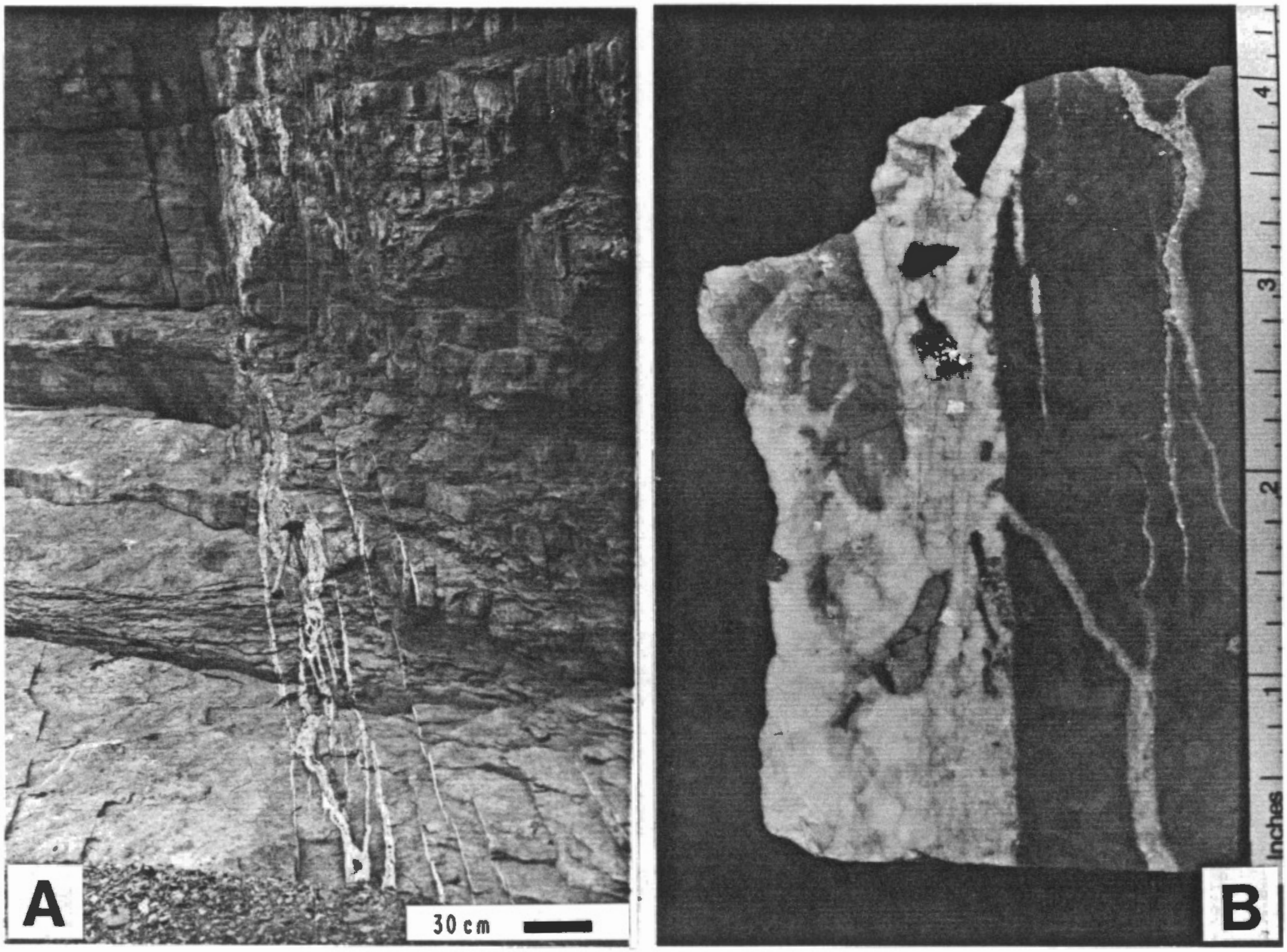


PLATE V : 22 A/16-5

PLATE VI - 22A/16-5

Photomicrographs of specimens D (A, B, C) and A (D). A. Fine, fibrous comb structure of calcite (white) between host rock below and galena cube above; plane-polarized light. Elsewhere along this contact between vein and host, no comb structure is evident. B. As A, in reflected light. C. Fragment of host rock partially enclosed in galena crystal; reflected light. The outlines of this crystal are crystal boundaries, except along the contact of the fragment. D. Tiny fluid inclusions are abundant in sparry calcite of vein; plane-polarized, condensed light.

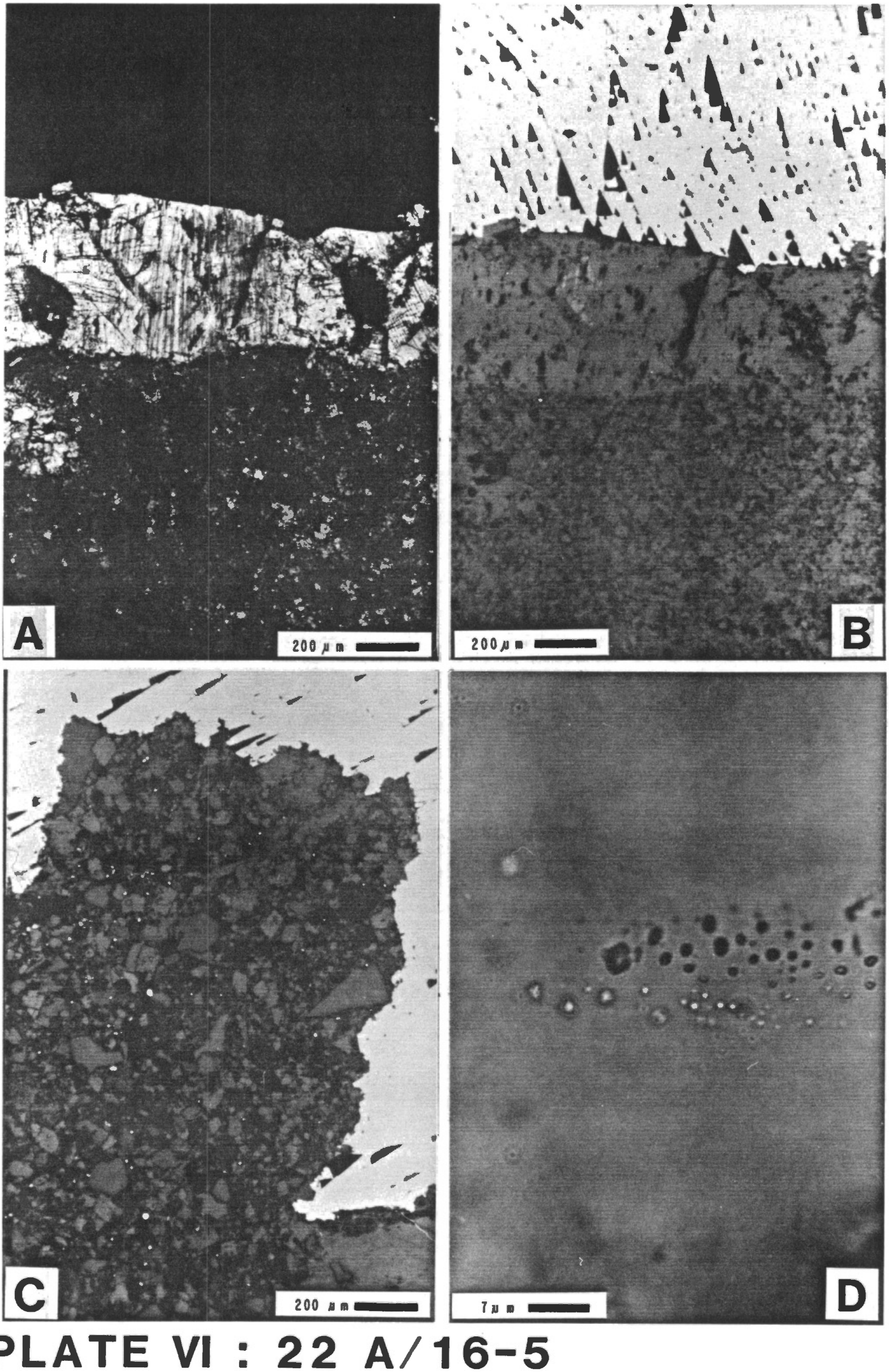


PLATE VI : 22 A/16-5

PLATE VII - 22A/16-7

Mozaic of photomicrographs of specimen C; plane-polarized light. See text (pp. 12-13) for discussion. Note that sphalerite (zone 4) is in contact with zone 3 but does not protrude into that zone (left-hand rim of the photograph); all other sphalerite crystals are entirely contained within zone 4. See also Plate VIII<u>B</u>, <u>C</u>, <u>D</u>.

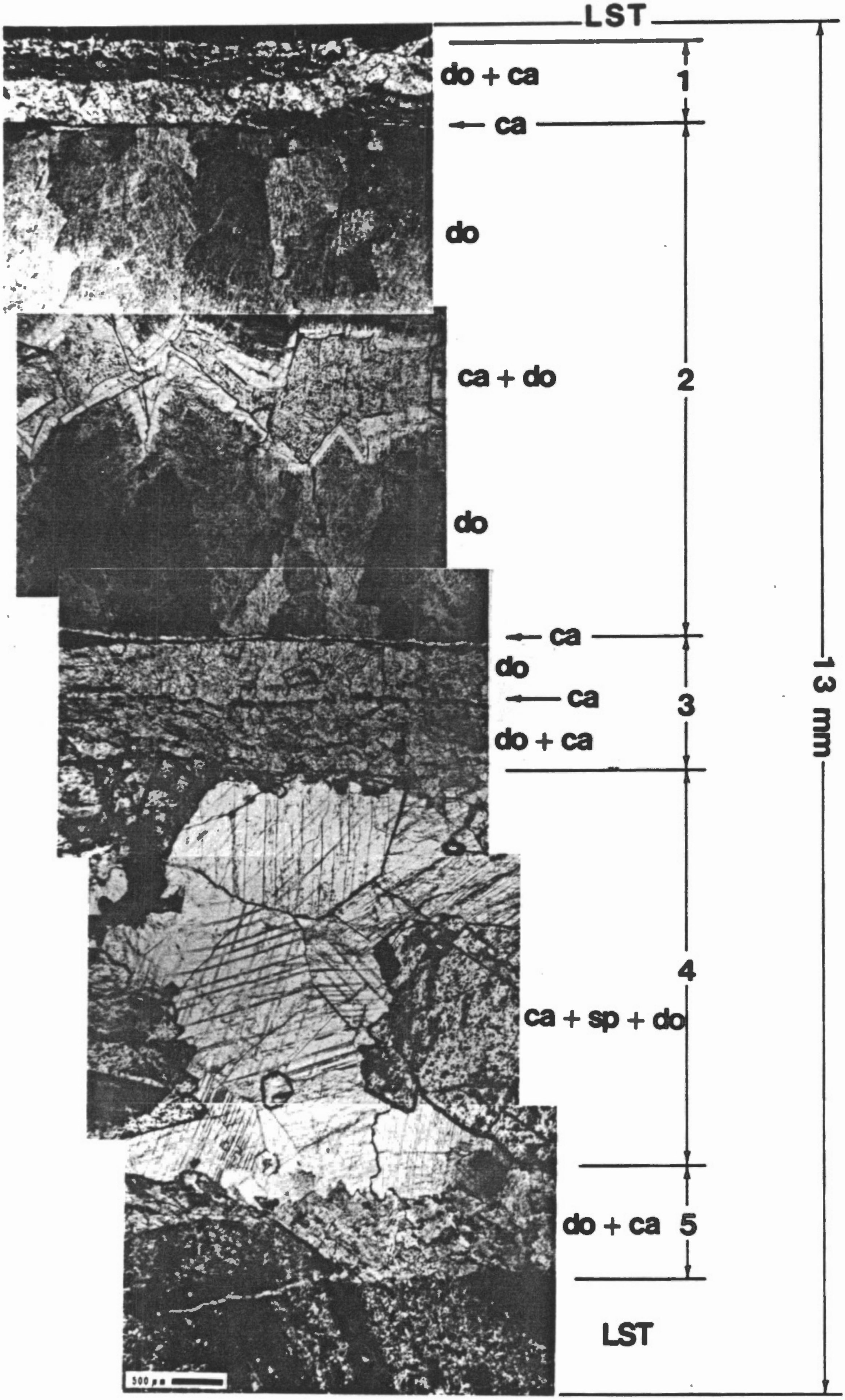


PLATE VII : 22 A/16-7

PLATE VIII

_A_. Cathodoluminoscope photomicrograph of 22A/16-2 (specimen C); cf. Plate VI_A_. _B_, _C_. Cathodoluminoscope photomicrographs of 22A/16-7 (specimen C), selvedge of vein and center of zone 2 of Plate VII respectively. All bright yellow spar is calcite, in _B_ probably dedolomite, in _C_ possibly recrystallized dedolomite. _D_. As _C_, in transmitted light; note cloudy saddle dolomite with clear terminations, and calcite with relatively coarse opaque particles (goethite?). All carbonates contain abundant tiny (~ 1 μm) fluid inclusions, but cloudiness is not due to these inclusions alone.

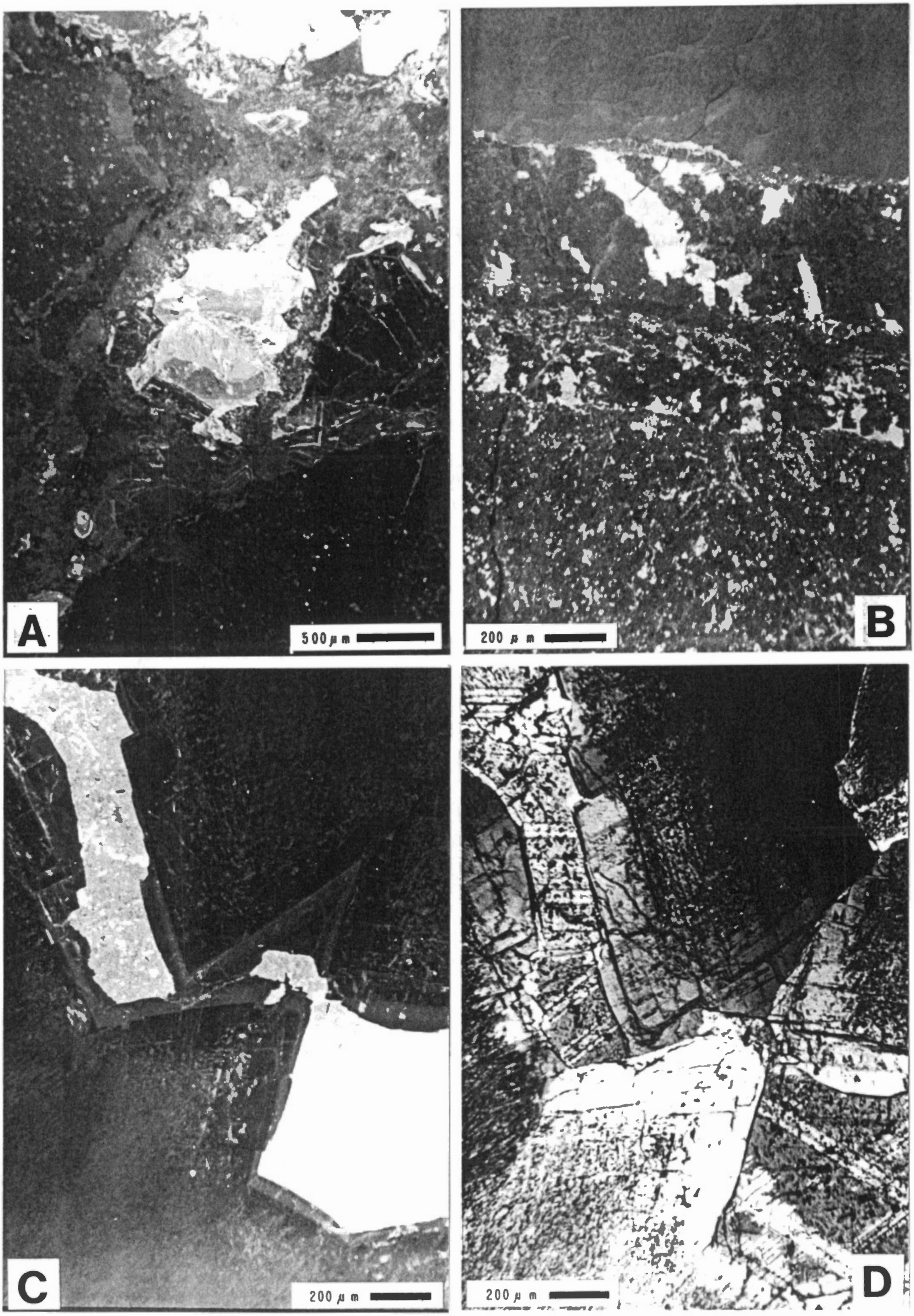


PLATE VIII :22 A/16-2 , 22 A/16-7

PLATE IX - 22H/4-4

Photomicrographs of specimen H (_A_, _D_) and F (_B_, _C_). _A_. Subhedral galena mantled by euhedral pyrite, reflected light. _B_. From bottom to top: imperfectly polished sphalerite crystal with mild "chalcopyrite desease"; euhedral pyrite (bright) with anhedral semi-inclusion (medium grey) of galena; galena at top right-hand side; pyrite with small, ill-defined galena inclusions at top center; all sulphides are in contact with gangue quartz (black); reflected light. _C_. Erratically angular vugs in quartz; plane polarized light. See discussion in text (p. 118). _D_. Example of a common, but relatively large, type of fluid inclusion in quartz; plane polarized condensed light.

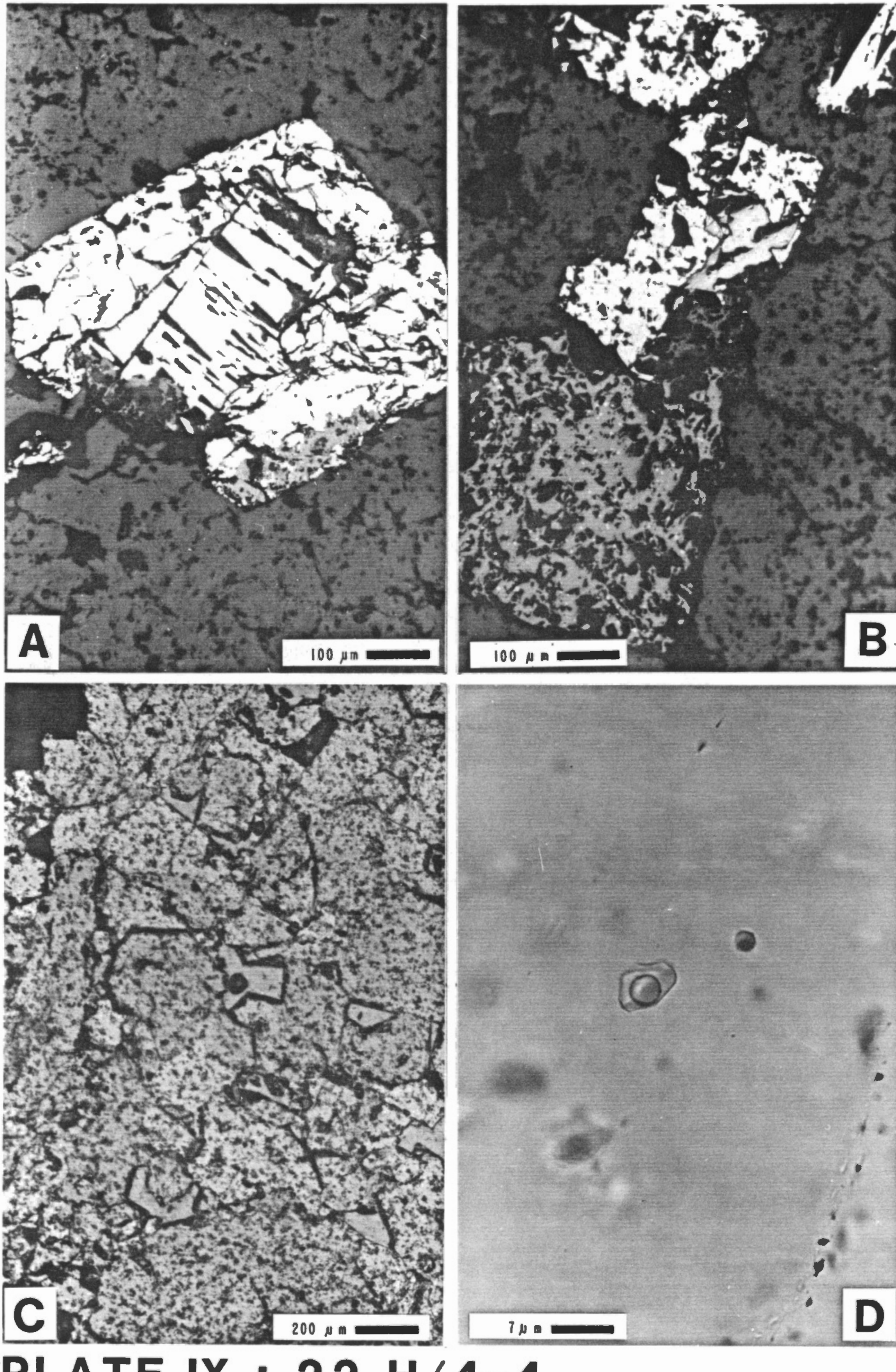


PLATE IX : 22 H/4-4

PLATE X - 22A/6-1

Photograph of polished face of specimen B. See description in text
(p. 120).

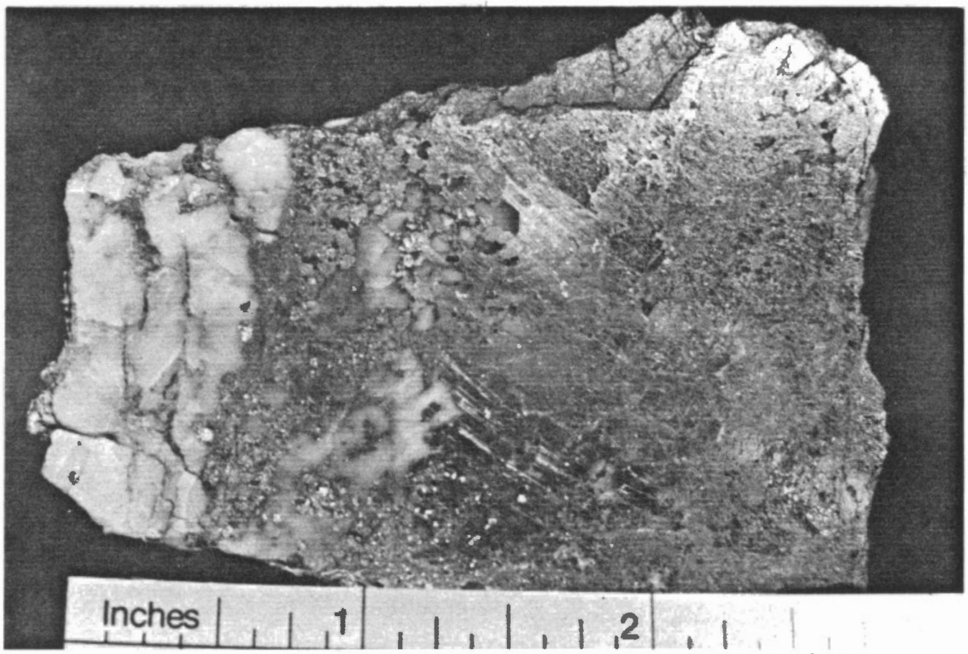


PLATE X : 22 A/6-1

PLATE XI - 21N/15-1

Photomicrographs of specimen B. A. Detrital quartz and single detrital grain of altered feldspar (dark grey) cemented by epitactic quartz, galena and traces of sphalerite; plane-polarized light. B. Detail of A, showing fluid-inclusion rich outline of detrital quartz grain and epitactic quartz rim, poor in fluid inclusions; plane-polarized light. C. Detail of A, showing slightly translucent sphalerite rimmed and masked by galena in interstice between quartz grains; plane-polarized light. D. As C, in reflected light; galena is bright, sphalerite is light grey and encloses two small chalcopyrite grains (bright) in upper corner of triangular filling of interstice.

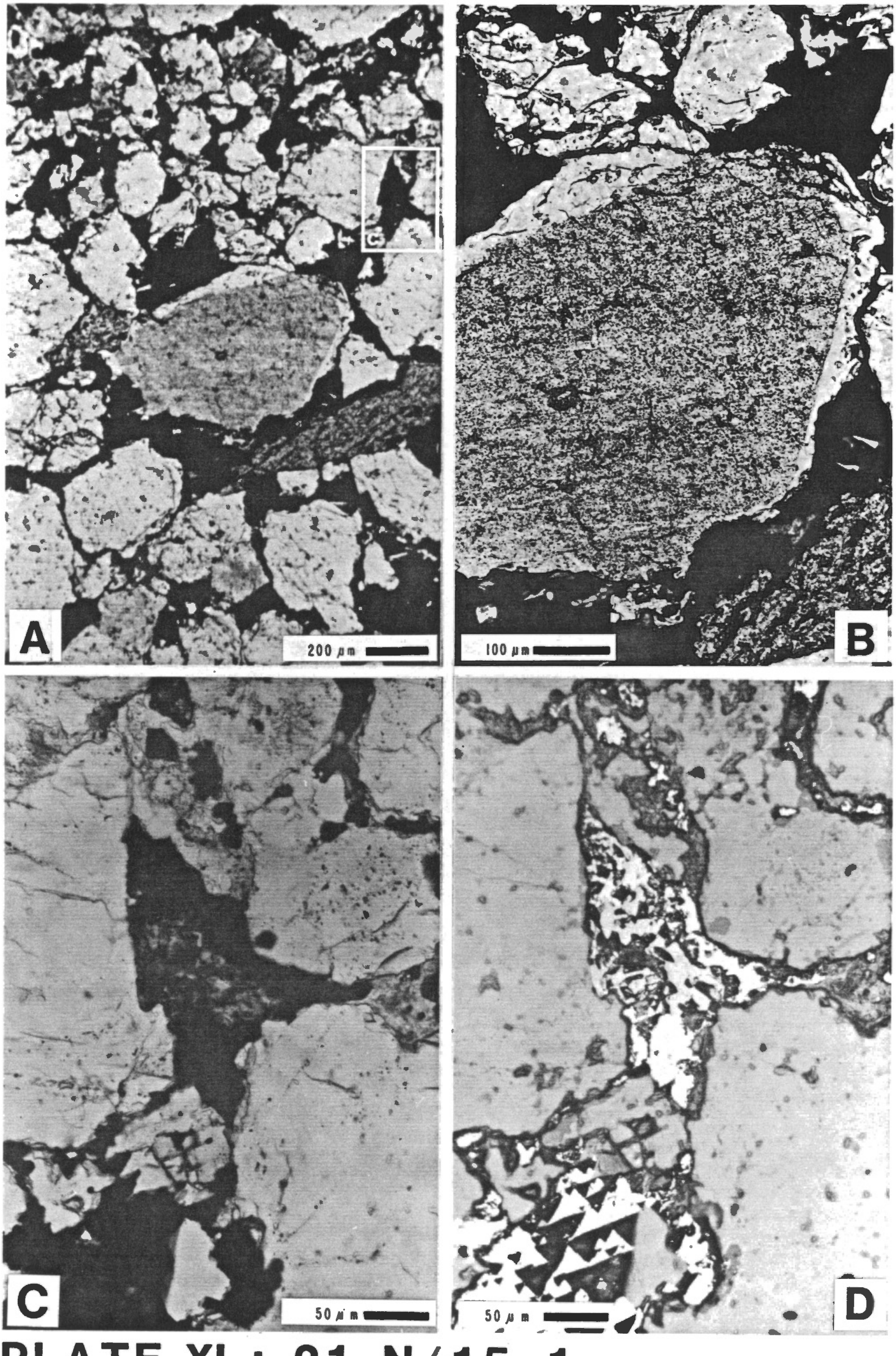


PLATE XI : 21 N/15-1

PLATE XII - 22C/7-4

Photomicrographs of specimen L, showing detrital quartz grains cemented by epitactic quartz, dolomite and galena. Note in _C_ the fluid-inclusion rich interior of the quartz grains, the cloudy rim (fluid inclusions and unidentified semi-opaque matter) separating the detrital quartz grains from the epitactic quartz cement.

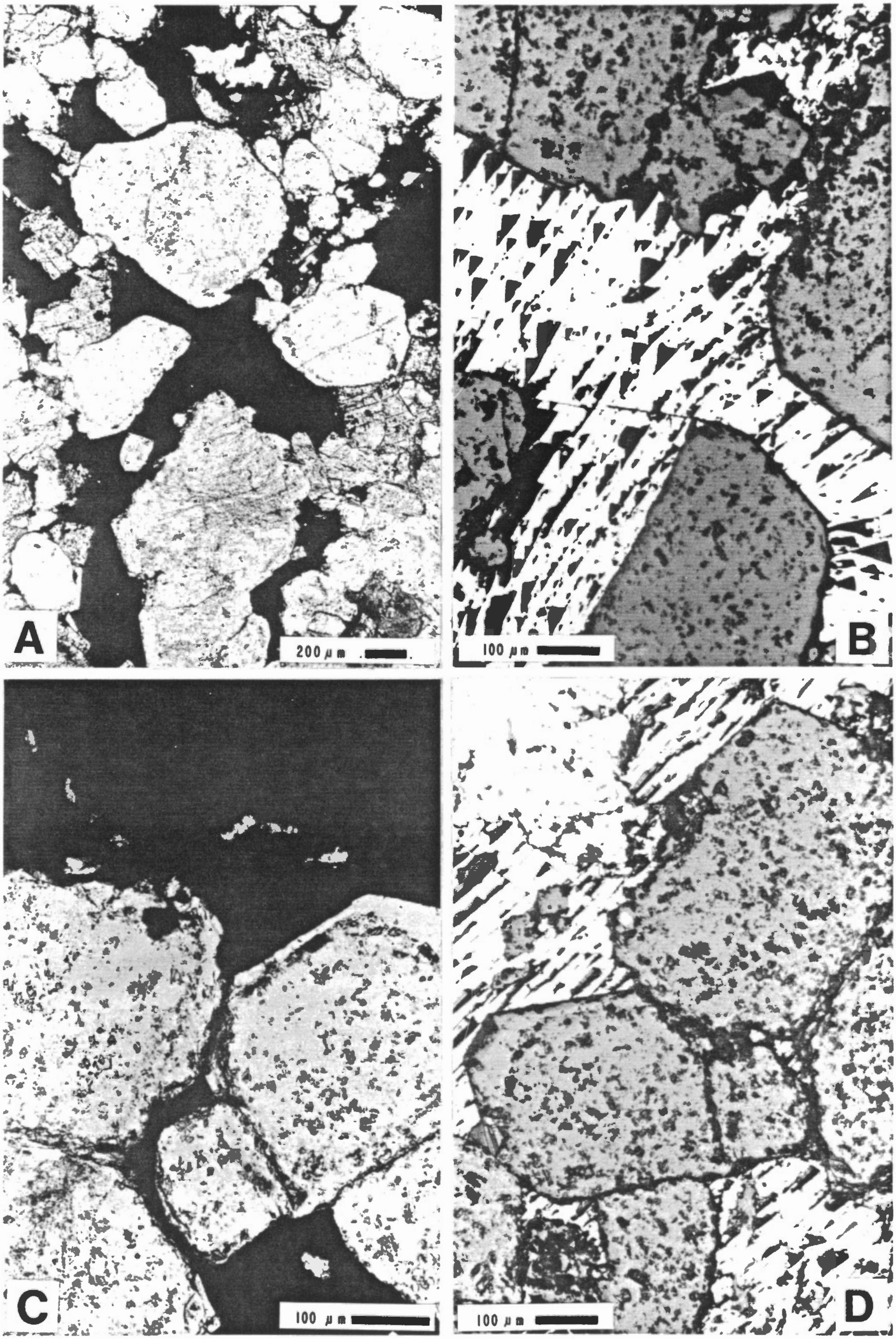


PLATE XII : 22 C/7-4

PLATE XIII - 22C/7-4

Photomicrographs of specimen L, showing other modes of occurrence of galena. A, B. Galena replacing a single or two contiguous detrital grains of albite. C, D. Colloform phosphate-rim around galena grain in phosphate nodule. See discussion in text (p. 126).

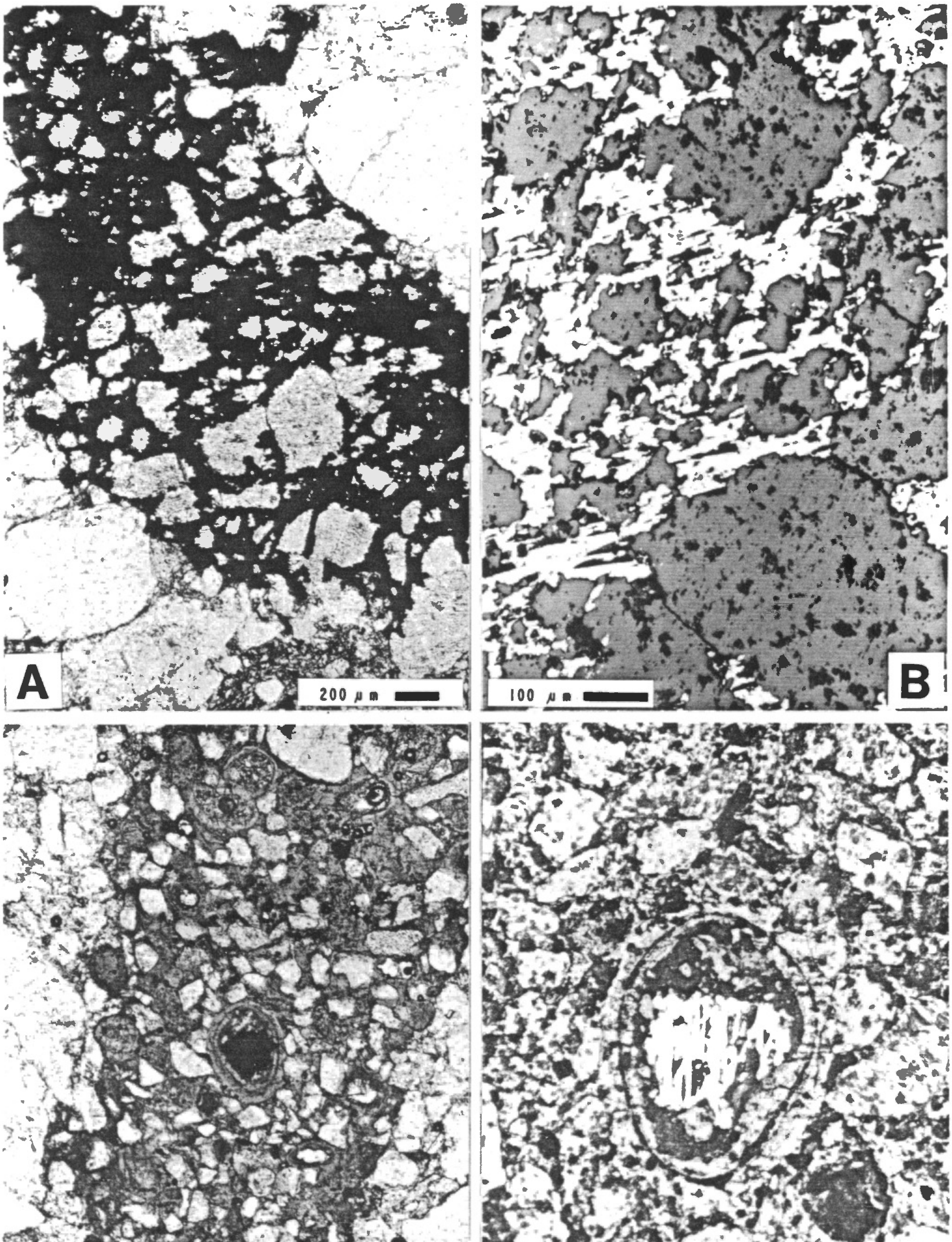


PLATE XIII : 22 C/7-4

PLATE XIV - 22C/7-4

Photomicrographs of specimens T (A, C), U (B) and S (D). T and S are lead-sandstones from underground; U is a polymictic calcareous conglomerate containing disseminated galena from the top of the hill above the adit. Description and inferences in text (pp. 126-127). In D, barite, and subordinate epitactic quartz and dolomite, cement detrital quartz and feldspar grains. Barite, locally invading detrital feldspar, possibly replaces in part earlier, more common cementing substances.

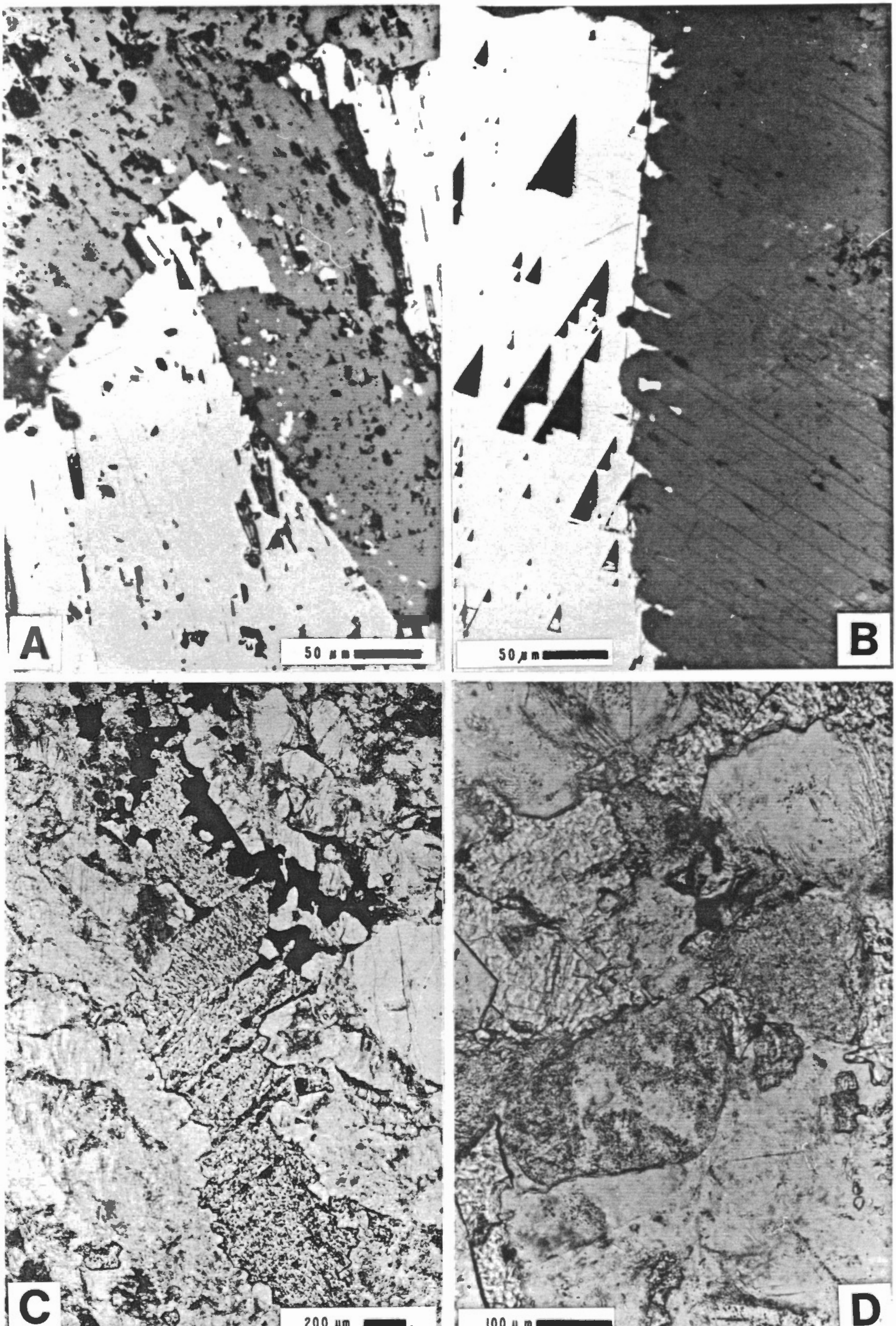


PLATE XIV : 22 C/7-4

PLATE XV - 22C/8-1

Photomicrographs of specimens F (A, B, D) and G (C). Description and inferences in text (p. 129). In C, the opaque grain (black), in the left-hand center of the photograph, is chalcopyrite; that in the upper right-hand corner is galena.

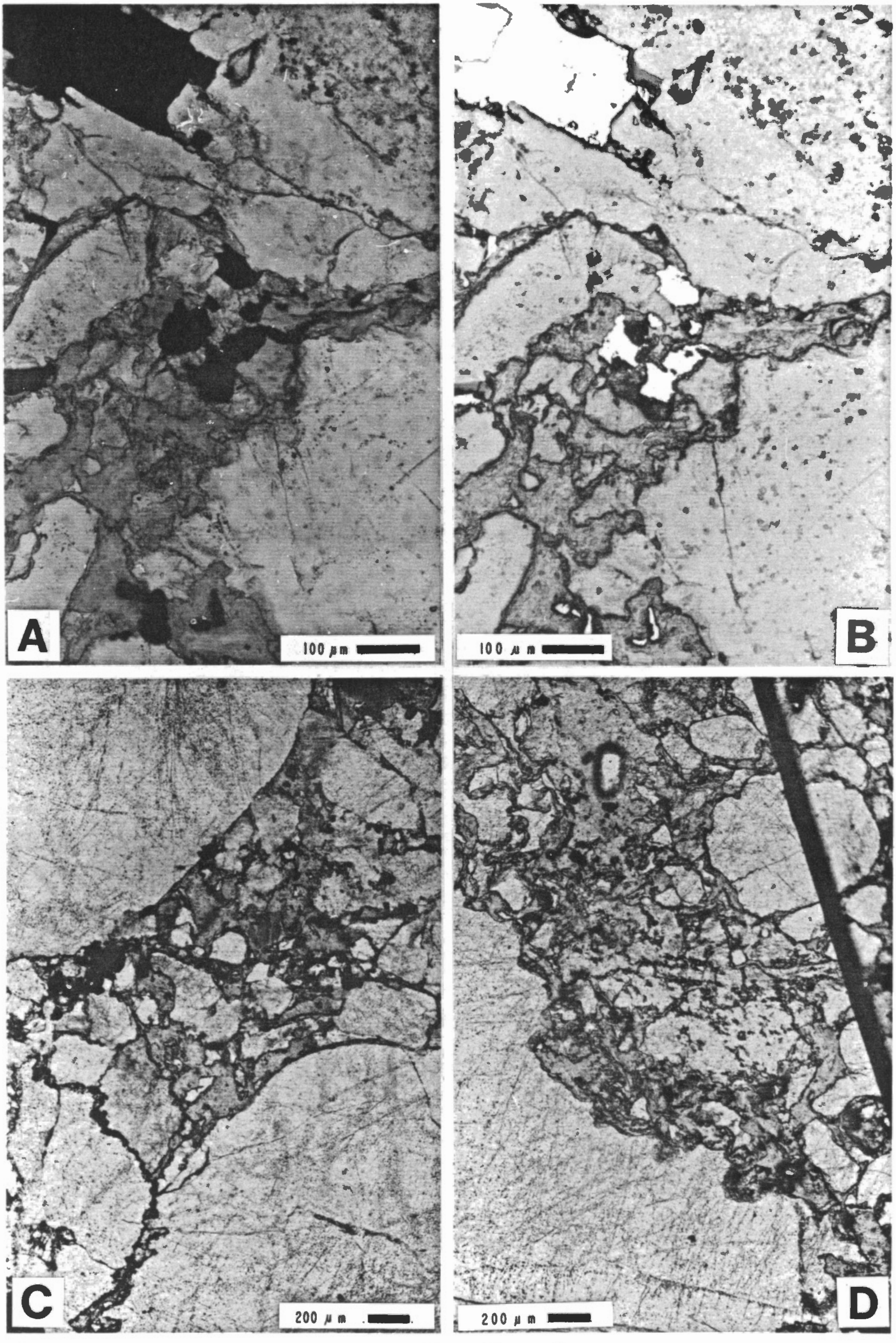


PLATE XV : 22 C/8-1

PLATE XVI - 22B/9-1

Photograph of polished face of specimen B. Description in text (p. 130).

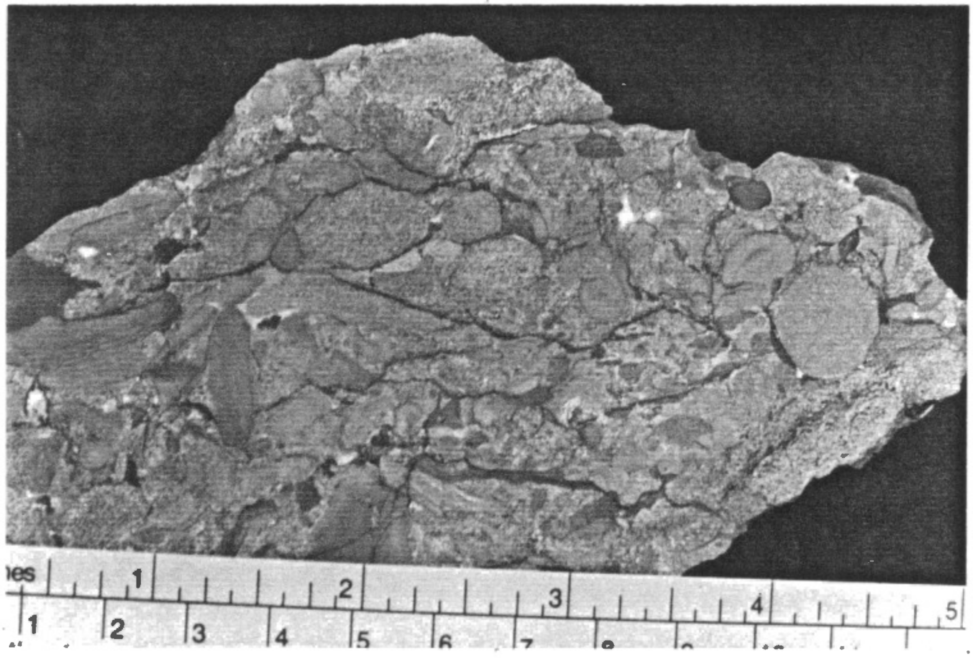


PLATE XVI : 22 B/9-1

PLATE XVII - 22B/9-1

Photomicrographs of specimen B (A, B, D) and photograph of specimen E (C). A. Sandstone matrix of mineralized conglomerate layer showing a few clasts (black), quartz and subordinate feldspar grains (white), chloritic grains (homogeneous grey), set in a dolomitic cement; plane-polarized light. B. Similar to A, showing "intrusion" of clast (black) into sandstone matrix ("soft-sediment deformation structure"); plane-polarized light. C. Mutual relations of clasts and sandstone-sulphide matrix; sulphides are galena (larger grain in lower left-hand corner), and stringer of galena, marcasite and sphalerite in order of decreasing abundance; non-polarized light. D. Unsuccessful attempt to show the relations so clearly displayed in C; plane-polarized light.

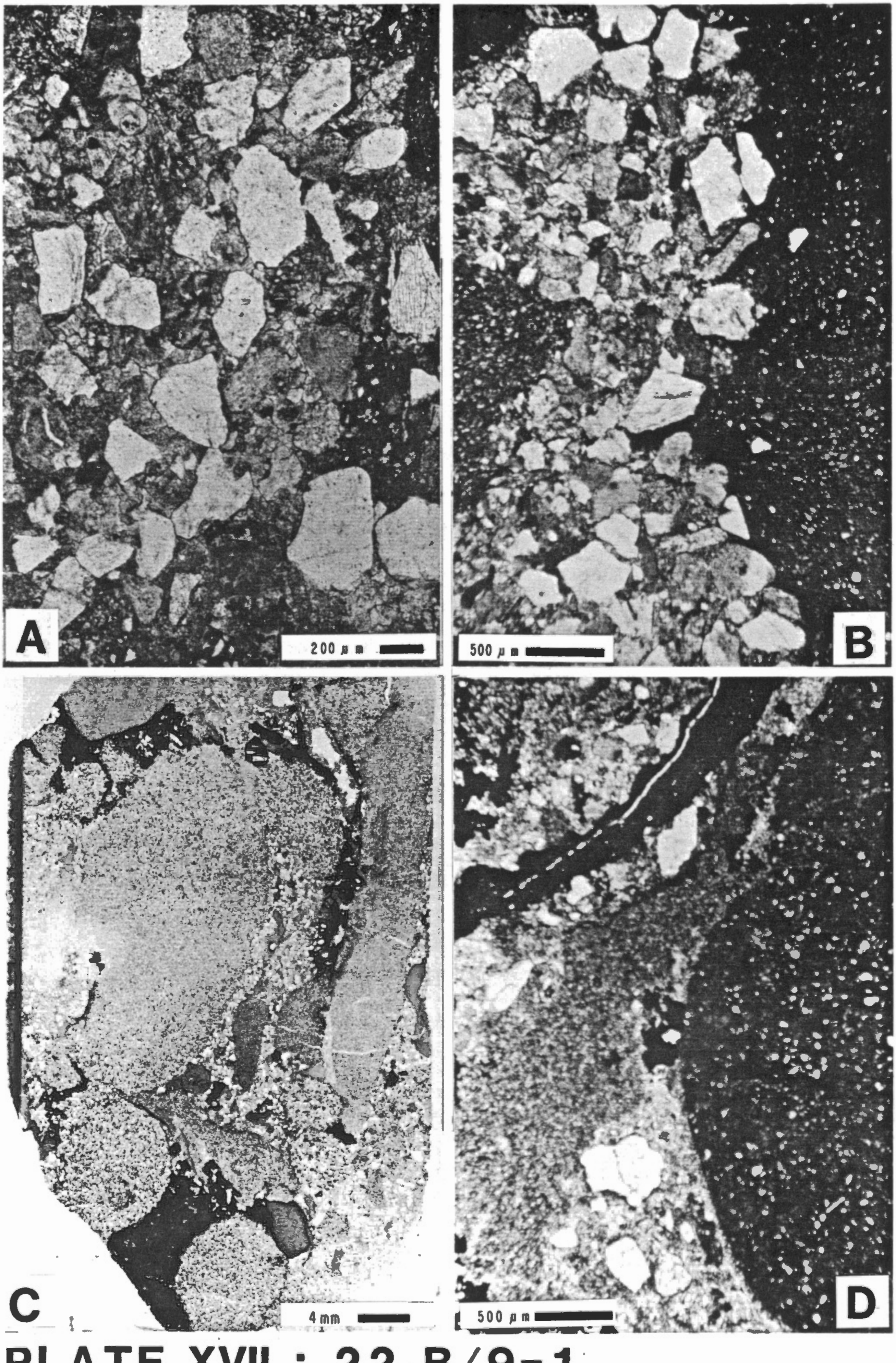


PLATE XVII : 22 B/9-1

PLATE XVIII - 22B/9-1

Photomicrographs of specimen B (A, B) and E (C, D). A. Dolomite rhombs, part of sandstone matrix, rim major sulphide aggregate; plane-polarized light. B. As A, in reflected light, showing partial marcasite rim around, and marcasite inclusions in, galena. C, D. Aggregate of zoned sphalerite crystals, intergrown with galena, and enclosing calcite grains; transmitted and reflected light respectively.

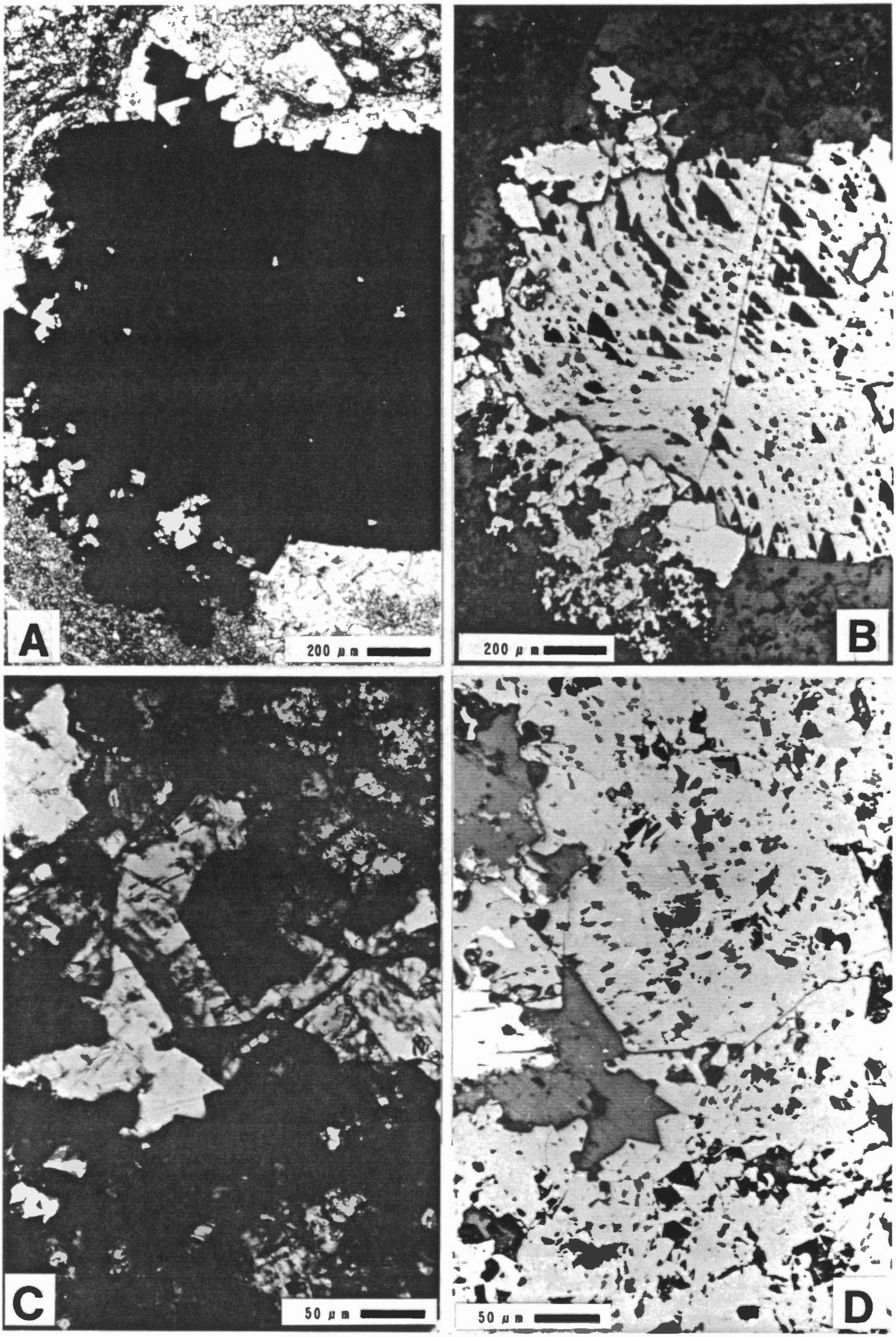


PLATE XVIII : 22 B/9-1