MINERALOGICAL MAGAZINE, DECEMBER 1981, VOL. 44, PP. 417-23

Reactions between uranium veins and their host rocks in Vendée and Limousin (France)

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ABSTRACT. Hydrothermal uranium veins, associated with the Hercynian leucogranites show important variations in their mineralogical, chemical and structural features in relation to the host rock lithology. These are described with particular reference to the Chardon deposit, Vendée where the veins cut granite, basic lithologies, and shales. The following features are described:

1. Changes in the thickness of veins near to contact zones, particularly those between granites and basic lithologies, lamprophyres, and shales.
2. Changes in the gangue mineral assemblage with the preferential development of carbonate in veins cutting basic lithologies, and of silica in veins which cut granite.
3. Paragenetic zoning in the veins in passing from granites to their metamorphic aureoles.

Comparisons between deposits of Vendée, Limousin, and Erzgebirge allow the following generalizations to be made:

1. Open faults and subsequent mineralization are concentrated at boundaries between competent and more plastic lithologies.
2. Mineralizing fluids cause wall-rock alteration characterized by the removal of Si from granite and of Ca, Mg, Fe from metamorphic and basic rocks.
3. The chemical and structural characteristics of wall-rocks are important controls on the mineralization but in acid lithologies the main controls on the pitchblende vein formation are the structural characteristics of the wallrock.

HYDROTHERMAL uranium veins associated with Hercynian leucogranites of the Variscan belt show different regional and local, morphological, mineralogical, and chemical features, depending on the nature of the host rocks and Geffroy and Sarcia (1960) recognized three types of hydrothermal veins: the Erzgebirge type in which mineralization occurs in shales, around the granites and is mainly associated with carbonates; the Utah or Colorado type, which is characterized by a U-Mo association with pitchblende-molybdenite-adularia as the principal mineral species; and the Limousin or Marche type which occurs within granite and in which the paragenesis is mainly siliceous. A similar classification has been established for vein-type uranium occurrences in the United States (Everhart, 1956). Such variations in the uranium ore bodies may reflect genetic processes including the nature and origin of the mineralizing fluids, the pressure-temperature conditions during mineralization and processes of deposition, or they may result only from the different geological settings of the mineralization.

Veins of the Vendée district of France (fig. 1), especially those of the Chardon (fig. 2) deposit provide a good example for study. In these deposits variations occur in the chemical and mechanical features of the host rocks of the same vein network, and in some cases of the same vein. Reactions between uranium veins and wallrock are similar in all of the Hercynian deposits and the features of the Chardon mine are compared with deposits in the following host rocks: metamorphic rocks around or occurring as enclaves in the Penaran deposit, South Brittany; granitoids of different chemical composition (Vendée); two mica granites and lamprophyres (Fanay deposit, Limousin); and differentiated metamorphic series (Erzgebirge).

The Chardon deposit

The main feature of the Vendée deposits is their localization along the contact zone of leucogranites, related to the South Armorican shear zone, with their surrounding metamorphic and/or magmatic rocks. Deposits within the granitic massif, or in the metamorphic units, are less common and are never more than one or two kilometers from the contact zone.

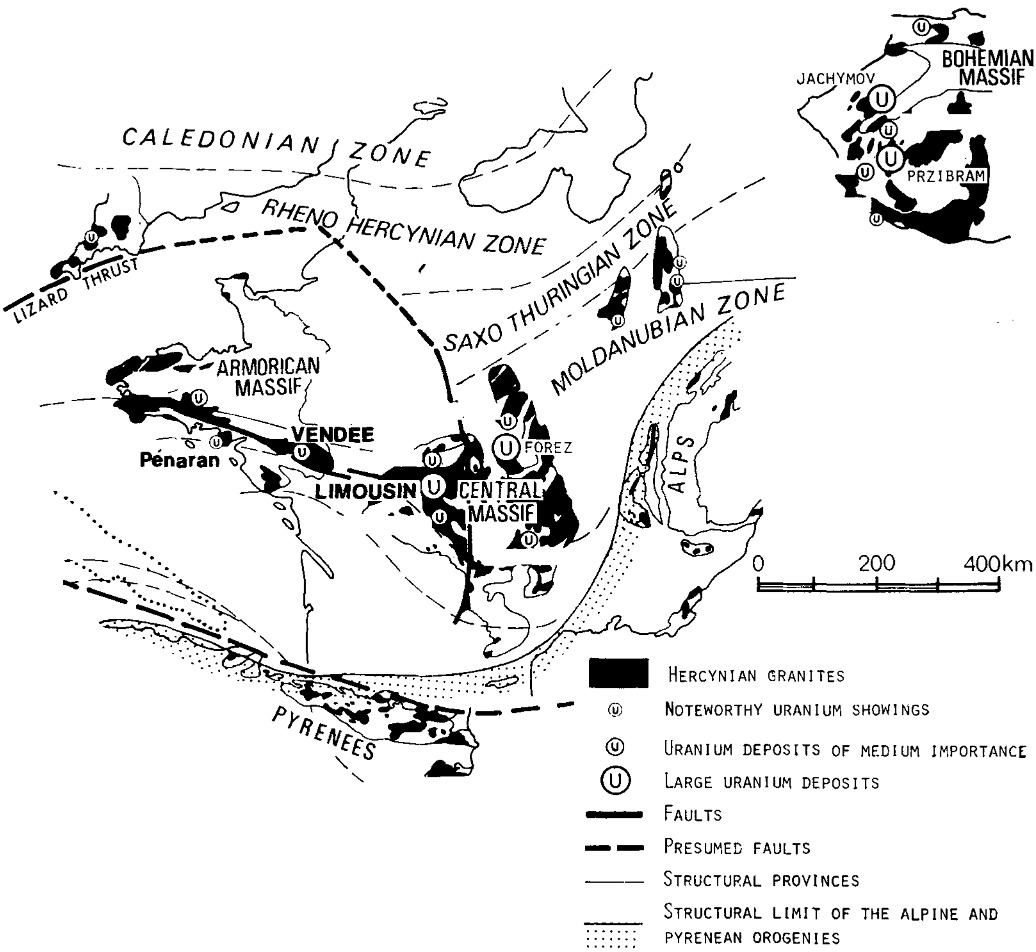

FIG. 1. Location of the main uranium deposits in the Variscan belt. (Modified after Cuney, 1974.)

Geological Setting

The Chardon deposit is located in the north-eastern part of the Clisson–Mortagne leucogranite, at the contact between a two-mica granite and a metamorphic series which is compressed between the granite in the south, and the Pallet gabbro to the north (fig. 2). Examples of the two-mica granite and the metamorphic series both occur in the Chardon mine (Cathelineau, 1979). The two-mica granite of Mortagne, which is porphyroid in part, shows an important mineralogical and textural evolution towards the contact. Progressive blasto-mylonitization produces sericite-rich layers (Leroy and Cathelineau, 1981), and is accompanied by the destruction of ferromagnesian minerals. The geo-chemistry of the granites is not significantly altered, however, and the alkalis in particular show very little variation.

The metamorphic series consists of three main tectonic units. From south to north these comprise: (*a*) a basic series of amphibolites, some of which are gabbros of the basement granulitic assemblage; (*b*) low-grade shists with chemical characteristics typical of shales; (*c*) a porphyroid unit, a deep blastomylonite, the origin of which has not been fully established. The structural relationships between the metamorphic series and the granite are those of a ductile zone and result from east–west dextral shearing and north–south compression. The north–south compression was caused by reverse thrusting of the granitic block.

The blastomylonitization is an early pheno-menon which has no relationship to ore deposition. It has mineralogical lineations related to plastic flow, which impart mechanical properties to the granite and to the metamorphic units. During later tectonism these east–west lineations created mechanical anisotropy which favoured faulting sub-normal to the lineation. Two types of faults can be recognized, the first trend north–south ($\pm 20°$) and are subvertical, the second trend north–south ($\pm 20°$) and dip at 60° to the west (fig. 2).

The mineralization occurs in tension joints, conjugate shear joints and extension zones, and is limited to the zone of shearing caused by the major tectonism of the area. The veins are considered to have formed during this tectonic event or immediately after, by hydraulic fracturing (Lillié, 1974). Veins cut all the metamorphic units without offset.

Mineralization

Common features of the uranium veins associated with granites in Vendée. The first, and sometimes only phase of mineralization consists of pitchblende and a sulphide assemblage in which the dominant sulphide is pyrite. This is followed by a second mineralizing phase with quartz and late iron hydroxides which are well crystallized or have radial structures and which are formed from the partial destruction of early pyrite. The chemistry of the final stage of mineralization depends mainly on the lithology of the host rocks (fig. 3). The oxidation state of iron changes continuously during mineralization with the sequences: hematite–pyrite–goethite and hematite–marcasite–goethite–melnikovite.

Variation. Variations in paragenesis which are related to the wall-rock lithology are shown in Table I. Remobilization of the mineralization is also indicated by lead loss from the pitchblende and disturbed isotopic ratios (Kosztolanyi, 1971). The lack of evidence of remobilization of the mineralization in the metamorphic rocks is noted.

Structural controls

At the Chardon mine, mineralized veins and thick breccias are developed near the contact with basic rocks, although the veins become narrower and sometimes terminate in the basic rocks (fig. 4).

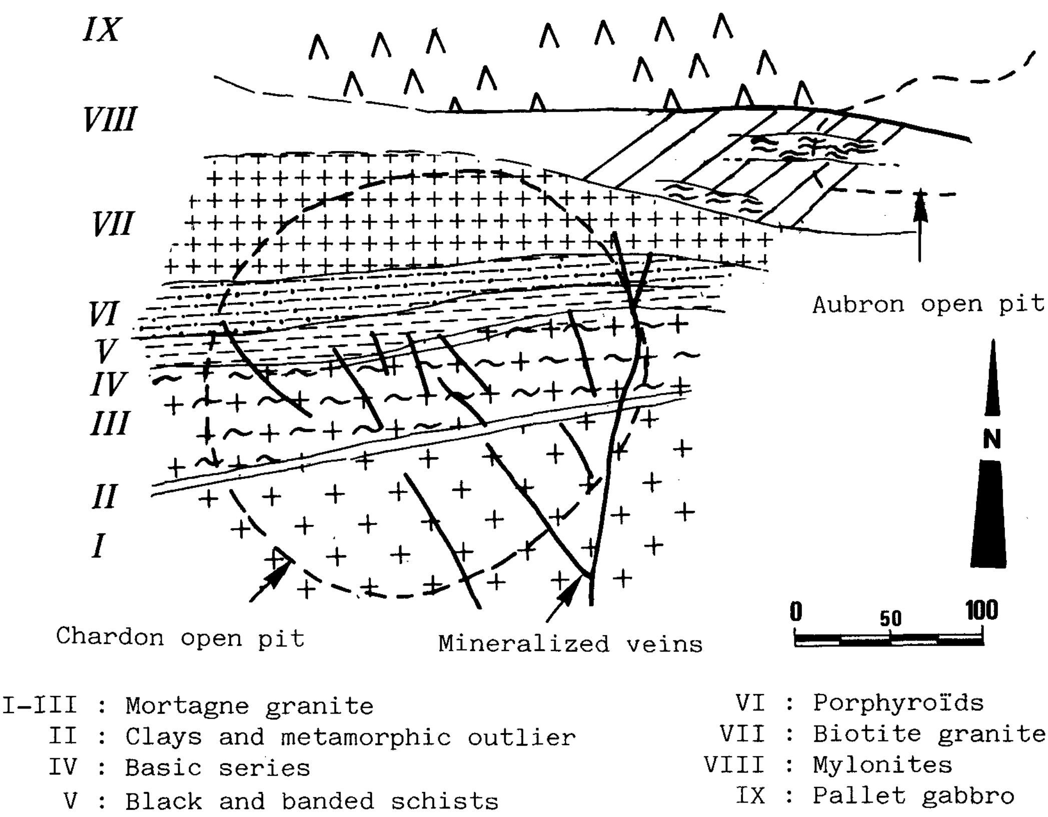

FIG. 2. Northern contact of the Mortagne massif in the Chardon mine (Vendée).

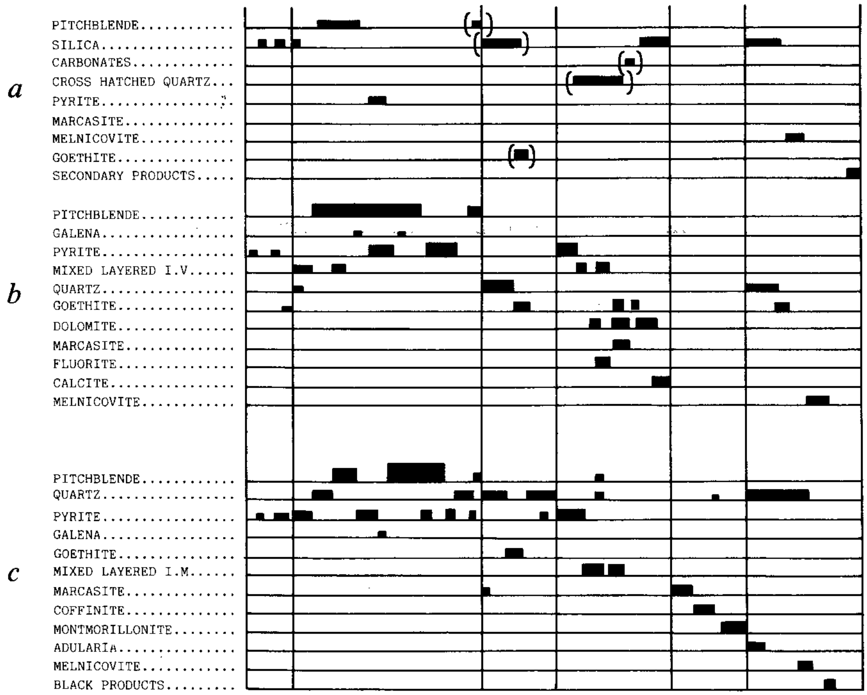

FIG. 3. Paragenetic sequence observed in the Chardon veins and related to different surrounding rocks. *a*: porphyroids; *b*: banded schists; *c*: granite. ( ); these minerals only appear in the transition zone between porphyroids and banded schists.

TABLE I. *Differences in uranium veins in relation to host-rock lithology*

	Granite	Porphyroid unit	Contact zone	Schist	Basic rocks
Vein thickness	Generally 1 cm (approx.)	Decrease and also disperse (fig. 4)		< 1 cm in black schist, > 1 cm in banded schist (to 1 dm)	< 1 mm
Minerals crystallized before pitchblende (growing perpendicular to wall rock)	Quartz combs	Tiny quartz combs		Clay minerals (partially ordered illite–vermiculite)	
Axial filling of veins; result of reactions between ore-forming fluids and host rocks	Entirely siliceous	Entirely siliceous	Tiny laminae of quartz in carbonates resembling the cross-hatched quartz of Bois-Noirs deposit (Cuney, 1974)	Carbonaceous	Carbonaceous
Replacement of pyrite inclusions in pitchblende	Partially or completely by illite and less abundant illite–montmorillonite			By illite–vermiculite and carbonates (sometimes in an axial position in vein)	
Later remobilization of mineralization	This consists of (1) a coffinite–marcasite–montmorillonite phase producing marked alteration of plagioclase (montmorillonization) up to 20 cm from vein (although it is emphasized that no alteration was associated with the pitchblende–sulphide stage); (2) quartz–adularia and quartz–melnikovite phases which produce vugs of quartz combs and black uraniferous material			Very weak	

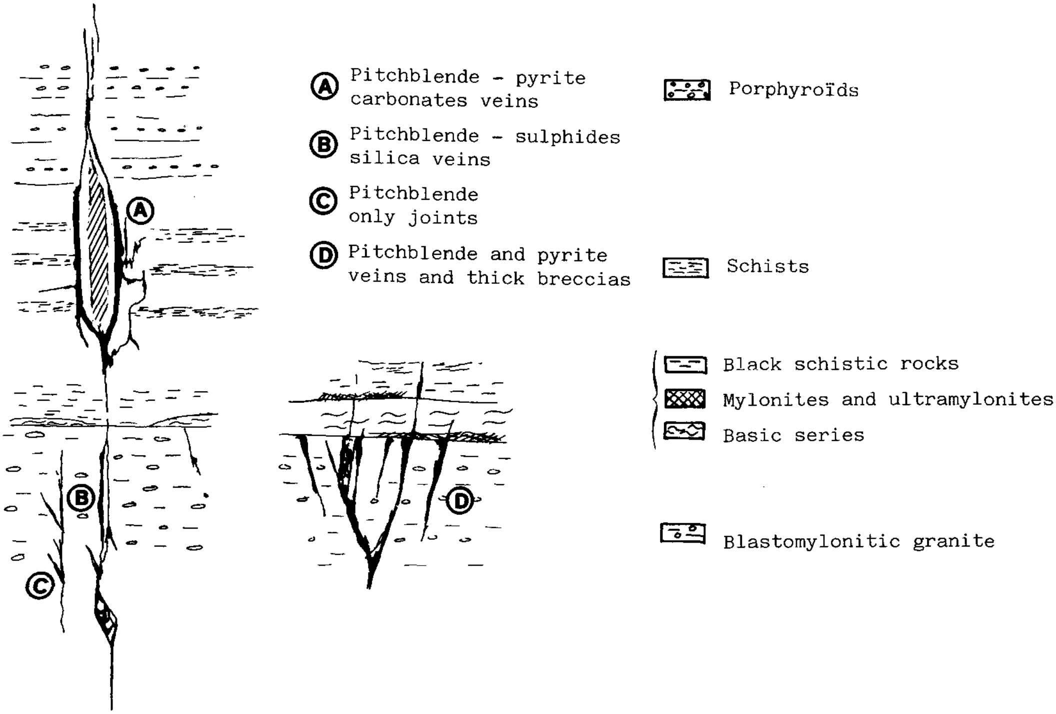

FIG. 4. Structural features of the Chardon veins (Vendée).

Similarly, uranium veins at Fanay (Limousin, France, fig. 5) cut lamprophyres consisting of augite, magnesian biotite, peridot pseudomorphs, apatite and magnetite, in a feldspar matrix (Leroy, 1978 *a* and *b*) in the St. Sylvestre two-mica granite. Veins are often larger near their intersection with lamprophyres dykes and frequently terminate within the dykes (fig. 5). Sarcia and Sarcia (1962) noted a strong correlation between the increase in size and the original thickness of the veins. Similar relationships have also been reported from the Penaran deposit (fig. 1) (Cathelineau, 1981*a*). In this occurrence mineralization is developed in a shear zone along the contact between a competent unit low Na, K-rich blastomylonite and strongly folded, more plastic, quartzitic schists. Mineralization is widespread in porphyroids, but does not cut schists, in which brittle fracturing is particularly limited.

The influence of mafic units and ductile units is generally mechanical. Ductile units create anisotropy in homogeneous environments whereas competent units open preferentially near contacts with the more ductile units. Furthermore the lack of open faulting in ductile units causes them to act as mechanical screens to fluid diffusion and migration.

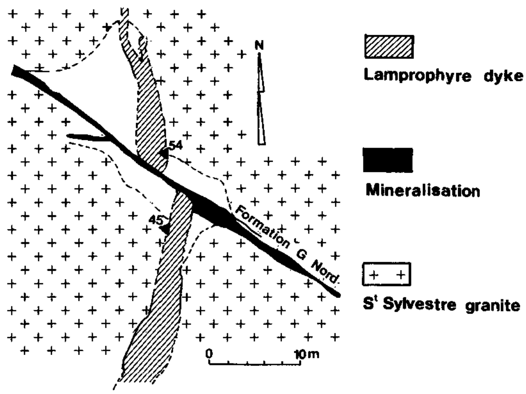

FIG. 5. Relation between two-mica granite–lamprophyric dyke and pitchblende vein (Fanay mine, Limousin, Northern G Formation).

Chemical reactions between wall-rock and uranium mineralizing fluids

At the Chardon mine important mineralogical variations occur as a function of host-rock lithology although alteration associated with pitchblende deposition is rare. The concentrations of several elements may be decreased and CaO–MgO concentrations in shales are depleted by 1–2% at 50 cm from veins; and SiO_2 in granites is depleted to 1% to 2% for a few decimeters to one metre from veins. In some cases a good correlation exists between Ca–Mg–Si depletion in the host rocks and the concentrations of these elements as carbonates or silicates in vein fillings (Cathelineau, 1981*b*). Similar variations in paragenesis occur at the Ecarpiere deposit where carbonates replace silica when the Ca content of the wall-rock exceeds approximately 1% in passing from granite–granodiorite host rock. At the Fanay mine, lamprophyres near mineralized zones show evidence of Ca, Na, and Mg depletion with an increase in K (Leroy, 1978*a* and *b*). These variations are reflected by muscovitization of feldspar, and the destruction of pyroxenes and biotites. In Vendée, this K-metasomatism induces in granitic environments the development of K-montmorillonite–adularia parageneses (Cathelineau, 1981*c*).

Finally, in the Erzgebirge district, mineralization around granite batholiths consists of veins in the following geological settings (Sokolova and Acheyev, 1972): (1) in basic to intermediate rocks (albite–chlorite schists, calcareous units, tuffs, diabases and carbonaceous schists especially those depleted in CO_2 during contact metamorphism), quartz–pitchblende–calcite veins are associated with zones of wall-rock alteration up to three m in thickness; (2) Fe–Ca–Mg alumino-silicates are altered to alkaline alumino-silicates, quartz, and calcite corresponding with leaching of Ca–Mg–Fe and an increase in CO_2–K comparable with the examples indicated above; (3) in more acid rock types, for example mica schists and quartzites, mineralization is scarce with weak chlorite–hematite hydromica alteration. In such host rocks no important transfer of elements is observed.

Leaching of Ca–Mg–Fe is observed elsewhere when the host rocks are rich in these elements (schists, tuffs, gabbros, lamprophyres); however, leaching is associated with different vein fillings in different areas. In Vendée, as in the Erzgebirge, Ca–Mg–Fe-rich wall-rocks are associated with the development of a carbonate-rich paragenesis. In the Vendée district uraniferous solutions have a low content of total dissolved solids and they are poor in CO_2, but in the Erzgebirge they contain a higher proportion of dissolved CO_2 (9.2 wt%) with a homogenization temperature which ranges between 150 and 220 °C. (Naumov and Mironova, 1969; Tugarinov and Naumov, 1969).

In Limousin no carbonates have been reported in pitchblende veins in lamprophyres. The uraniferous solutions are CO_2-rich, however, and the temperature is high (340–50 °C) (Leroy, 1978*a* and *b*). Under these conditions the lack of carbonates may be explained by the formation of soluble Ca–Mg bicarbonates.

Finally, an appreciable variation in the Ca, Mg, and Fe content of pitchblende is evident. For example pitchblende from Vendée and Bretagne has a higher Ca content than pitchblende in mineralization in granite from Limousin and Forez (Cathelineau *et al.*, 1980). The movement of elements between wall-rock and uraniferous solutions is also important for trace elements such as Cu, Pb, Bi, and Se which occur as sulphides, selenides, and sulphosalts in mineralogical sequences zoned from granite to their surrounding rocks (Cathelineau, 1981*b*).

Summary

The physical and chemical characteristics of the host rocks of vein-type pitchblende deposits are important in determining the morphological and mineralogical features of the veins.

1. Open faulting develops preferentially at boundaries between competent and more ductile lithologies; for example, the margin of veins of lamprophyre at Fanay, basic units at Chardon, and strongly folded schists at Penaran are all associated with open faults.

2. Where veins cut Ca–Mg–Fe-rich rocks, carbonates may precipitate as disseminations in the wall-rocks or with pitchblende in the veins. Silica is leached from the wall-rocks where veins cut acid rocks such as granites and Cu, Pb, Bi, and Se also show behaviour consistent with the findings of Tugarinov (1972).

3. Pitchblende deposition results from modification of the physical and chemical characteristics of uraniferous solutions. Wall-rocks have a 'mechanical' influence since the opening of fractures and the resulting porosity reduce pressure (Mullis, 1976). In Limousin this mechanism causes solutions to boil with destruction of uranyl-carbonate complexes (Leroy, 1978*a* and *b*). The second effect of wall-rocks is the exchange of elements between wall-rocks and solutions with pitchblende deposition occurring as a result of shifts in equilibrium. In acid lithologies without mafic units, the formation of pitchblende veins is due mainly to mechanical influences.

4. The structural and stratigraphical data in this paper provides a data source for the development of future geochemical/equilibria models for uranium transport and deposition in pitchblende veins.

Acknowledgements. This study forms part of a research programme at the Centre de Recherches sur la Géologie de l'Uranium. The authors thank the staff of the Compagnie Générale des Matières Nucléaires, (Vendée and Limousin), for their co-operation and assistance and the Centre de Recherches Pétrographiques et Géochimiques for technical contributions. Peter Pollard helped to translate the manuscript into English.

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[*Revised manuscript received 3 August 1981*]