Sulfide Deposits Associated with Cl Metasomatism along Thrusts in Black Shales, Tsodilo, Botswana

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INTRODUCTION.

The Tsodilo prospect area is found at the NW part of Botswana, close to the Okavango delta, about 100 km NW of the Maun town (Fig. 1).

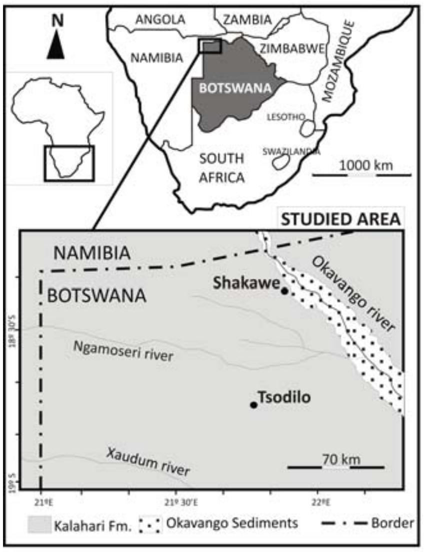

fig 1. Situation of the study area.

Most of the studied area is covered by thick series of Kalahari continental sediments and calcretes, and outcrops of mineral deposits are scarce. However, regional geophysical exploration surveys in NW Botswana applied by Tsodilo Resources Ltd allowed the discovery of important magnetic anomalies, coupled in many cases with conductivity anomalies. These anomalies are aligned defining trends approximately N-S. Systematic drilling along these anomalies allowed defining several styles of mineralization: sulfide veins associated with thrusts, sulfide veins in granites, skarns, sedex and IOCG.

The aim of this contribution is to provide information on the syntectonic sulfide veins.

GEOLOGY.

The area consists of an Archaean gneissic basement unconformably overlain by sedimentary series of PanAfrican age. These Proterozoic series have strong lateral and vertical changes of facies and thickness. Sedimentary domains can be established on the basis of the dominant lithotypes in the stratigraphic profiles. In some areas carbonate platform facies dominate, whereas other domains are made up by thick sequences of black shales and quartzites, with minor metabasites and conglomerates. These sedimentary domains are limited by the above mentioned N-S trending thrusts. Therefore, this type of geometrical relationships between tectonics and stratigraphy can be explained by PanAfrican tectonic inversion affecting a Proterozoic riftogenic basin. The ensemble was affected by regional metamorphism in amphibolite facies.

Intrusives in the area consist of granitic rocks ranging in composition from diorite to leucogranite. These granitoids produce the development of skarns when are found intruding limestones. Intrusion-related veins with potassic alteration, sometimes accompanied by tourmalinization, contain Cu-Pb-Mo ores. Sedex sulfide deposits are found in the black shales; the limestones and quartzites may be replaced by IOCG.

Some serpentinized ultramafic bodies also occur, but their textural patterns and their setting suggest that they correspond to ofiolites.

SULFIDE MINERALIZATIONS IN SYNTECTONIC VEINS.

These mineralized veins occur in thrust surfaces and can be traced along tens of kilometers. Veins are very irregular, and consist largely of quartz and pyrrhotite (which explain the magnetic anomalies associated with thrusts), with minor amounts of other minerals. Veins are of type "pinch-and-swell"; maximal thickness does not overpass 10 cm. Veins are often arranged as subparallel sets, producing mineralized bands whose are several meters thick.

Alteration in the vein selvages may consist of albitization, scapolitization, and biotitization. Albite may occur inside the vein or along the selvages. It develops euhedral short prismatic crystals, in the range between several millimeters and a centimeter. Twinning on {010} is always present; these crystals do not have zoning and are unaltered. Scapolitization is very common, and produces subhedral prismatic crystals. Scapolite crystals may replace albite (Fig. 2).

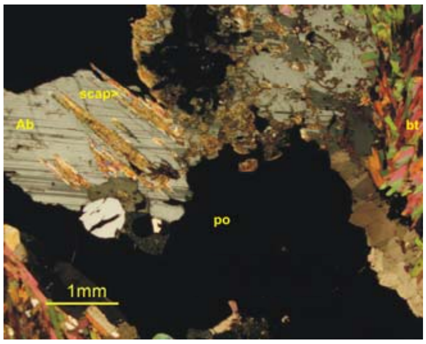

fig 2. Scapolite (scap) in a mineralizaed vein replacing albite across the twins (ab). The ensemble is replaced by pyrrhotite (po). Biotite (bt) is found AT the exocontact.

palabras clave: Sulfuros, Telururos, Oro, Cabalgamientos, Escapolita.	***key words:*** Sulfides, Tellurides, Gold, Thrusts, Scapolite.

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The scapolite is intermediate between marialite and meionite, without a silvialite component (Fig. 3).

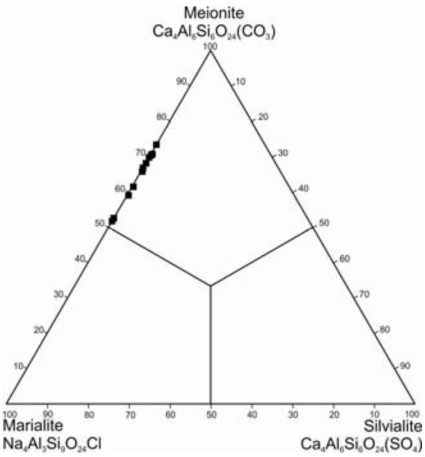

fig 3. Composition of the scapolite crystals associated with the syntectonic sulfide veins. Note the high content of marialite component.

Biotite may be extensively produced in the exocontact of the veins and has a eastonitic composition. However, the most remarkable aspect on its composition is the Cl content, which may achieve up to 0,17wt% in the vicinity of the veins.

These biotite enrichments are accompanied by a strong enrichment in fine-grained REE-Th-U minerals such as allanite-(Ce), monazite-(Ce), xenotime-(Y), ancylite-(Ce), cancioancylite-(Ce), bastnäsite-(Ce), thorianite and uraninite

The mineral sequence has 6 stages. A first stage (S1) produced the alteration of the host rocks and a first generation of gangue minerals, such as albite, tremolite, biotite and quartz, in some cases accompanied by tourmaline. Calcite is common at this stage, and may have been accompanied by small amounts of apatite and REE phosphates. A second stage (S2) was characterized by the replacement of the above minerals by quartz and late pyrrhotite. This stage was volumetrically the most important in the assemblage of the veins.

The third stage (S3) was also important. Chalcopyrite replaced pyrrhotite along grain borders and small veinlets accompanied by lesser amounts of chlorite and molybdenite platelets. Chalcopyrite is abundant enough to be considered as a possible valuable mineral, depending on the total content of this mineral in the ores.

The fourth stage (S4) was characterized by tellurides (melonite, altaite, bismuth tellurides and hessite), probably indicating a very low S activity, accompanied by native gold. All these minerals are extremely fine grained, and occur rimming grain borders and infilling small fractures of other minerals. This stage contains gold and precious metals and it should be studied in more detail in additional samples. Probably the mineral association at this stage was more complex than indicated above.

The fifth stage (S5) was probably triggered by an increase in the sulfur activity, because pyrrhotite was replaced by pyrite. This process was accompanied by the deposition of several sulfides of Pb, Zn, Ni. These sulfides are galena, a Cd-rich sphalerite and millerite. Pyrite was the only mineral spread out in this stage, and the other minerals are found only in trace amounts

A late generation of chalcopyrite was probably produced at this stage. The sixth stage (S6) resulted in the deposition of calcite and ankerite in small cracks, accompanied by lesser amounts of REE minerals. Many of these minerals contain U and Th, and hence they may account for the radioactive level that may help in the exploration of deposits of this type.

DISCUSSION.

The available data suggest that the deposit consists of an assemblage of sulfide-quartz-carbonate-scapolite-albite syntectonic to late-tectonic veinlets distributed through highly metasomatized anoxic turbiditic metasediments. The mineralizing fluids seem to be alkaline, owing to the extensive development of albite and its replacement by scapolite.

Very similar deposits are very common in the Proterozoic series in Fennoscandia (Eilu & Weihed, 2005). As in the case of Botswana, all these deposits occur as veinlets hosted by black cherts, and they have a typical regional hydrothermal alteration, consisting in the development of, biotitization, albitization, silicification, scapolitization, carbonatization, sulfiditization and, in some cases, tourmalinization (Eilu & Martinsson, 2007). Scapolite is the dominant mineral and can be regionally spread. It is generally rich in the marialite component, hence, in Na-Cl.

This type of deposit has been interpreted as produced by the action of hydrothermal fluids connected with acid intrusives (Lindblom et al., 1996), and similarities and a certain grade of consanguinity or overprinting with IOGC deposits have also been suggested (Wanhainen, 2005). The regional occurrence of scapolite alteration has been interpreted as the product of regional circulation of highly saline fluids (with possible evaporitic influence) across regional rocks at high metamorphic temperatures, thus favouring the development of scapolite (Weihed et al., 2008). Although some deposits are hosted by igneous rocks, most of them have been found hosted by black schists. In fact, the mineral association is interpreted using this fact, because the carbonaceous reducing rocks can be an effective trap for many redox sensitive elements (Eilu & Martinsson, 2007). This reducing trap can explain the association of the containing minerals with U-Ni-Co-U-Th-Mo-Fe-S-Te-Ag-Cu-Bi-As. Gold is likely to be transported in the form of chloride complexes, and the precipitation of scapolite would reduce the chlorine activity in the fluids, and hence, the destabilization of these complexes and the precipitation of gold. Therefore, the occurrence of scapolite, coupled with the existence of reductive traps as thick units of black shales, is a good criterion for exploration of these types of deposits worldwide.

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