

“Pombais Unit”, Lower Morais Ophiolite Complex, (NE Portugal): sulphide mineralisation and lithogeochemistry

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RESUMO

Palavras-chave: Ofiolito Inferior de Morais; unidade de Pombais; carreamentos; gossans; sulfuretos.

O recém definido Ofiolito Inferior de Morais na região da Junqueira é constituído por uma série de escamas com lavas máficas-xistos verdes da Unidade de Pombais separados por zonas de gossan que ocupam as caixas de falha desta lâmina tectónica. A unidade de Pombais foi alvo de estudos de petrografia de minerais opacos e litogeoquímica para investigação da possibilidade de remobilização hidrotermal de metais e a sua concentração durante os primeiros estágios de rifting oceânico. O estudo revela que a Unidade de Pombais está fracamente mineralizada no que diz respeito a minerais opacos. No entanto, pirite, calcoprite e covelite foram identificados. Igualmente ocorrem em maiores quantidades minerais de ferro e enriquecimento supergénico de malaquite. Os resultados da litogeoquímica indicam que as zonas de gossan foram usadas para canalizar e concentrar metais base como o cobre e que os primeiros estágios de rifting oceânico não são produtivos na concentração de metais preciosos.

ABSTRACT

Keywords: Lower Morais Ophiolite Complex; Pombais Unit; Junqueira; thrust splays; gossans; sulphide minerals.

The recently defined Lower Morais Ophiolite Complex in the Junqueira region is made up of a series of repeated slices of mafic lavas-green schist (making up the Pombais Unit) separated by prominent gossan-filled thrust fault zones, as a result of thrust splays overthrust under the classic Morais Ophiolite Complex (Intermediate Allochthonous Complex). The Pombais Unit was the target of ore petrology and lithogeochemistry studies to investigate the possibility of hydrothermal fluid movement and remobilisation of metals during the initial stages of rifting and whether this resulted in anomalous concentrations of precious metals. The study has found that the occurrence of ore minerals is very scarce although there are indications of pyrite (+ chalcopyrite; ± covelite) and a plethora of Fe-bearing minerals as well as supergene enrichment of malachite. The lithogeochemistry indicates that the gossan zones have indeed been used as fluid pathways and concentrated the base metals such as Cu. The precious metal content of the Pombais Unit is low and indicates that the initial stages of rifting are unproductive with respect their concentration.

Introduction

The *classic* Morais Ophiolite Complex has traditionally been considered as the Intermediate Allochthonous Complex by Pereira *et al.*, (2000). However, the recent definition of a Lowermost unit of this ophiolite complex (see Pereira *et al.*, this volume) and the occurrence of repeated thrust slices/scales marked by the development of gossans and supergene enrichment of Cu-bearing minerals, has prompted investigation into the precious (and base/transition metal) potential of this Lower (Morais) Ophiolite Complex.

The outcropping mafic lavas and green schists belonging to the Pombais Unit, near Junqueira, are a sequence repeated through thrust splays. Each thrust sheet is separated from the next by a gossaniferous horizon, which would seemingly provide an adequate pathway for the hydrothermal migration of fluids and hence, a repository for precious, base and transition metals. The ensuing discussion aims to illustrate some of these features through lithogeochemistry and ore petrography.

Geological setting of the Morais Ophiolite Complex

Stratigraphically, the (classic) Morais Ophiolite Complex, as the name implies, is a complete slice of oceanic crust, which is repeated through thrusting and results in two units namely, the Morais-Talhinhas Unit and the Izeda-Remondes Unit dated Silurian-Lower Devonian in age. The Intermediate Allochthonous Complex is wedged between an Upper Allochthonous Complex comprising, from bottom to top, Vale da Porca and Caminho Velho Units (Uppermost Proterozoic in age; Gabbros and high-grade metamorphic rocks), Lagoa Gneisses (Uppermost Proterozoic in age; Augen-gneisses), Lagoa Micaschists (Uppermost Proterozoic-Cambrian in age; micaceous schists and metagreywackes with intercalations of tuffs) and Dolerite dykes and sills (Pereira *et al.*, 2000) and a Lower Allochthonous Complex, essentially made up by the Centro-Transmontanas Units defined by Ribeiro (1974) and comprising, at the top, the Lower Morais Ophiolite (LMO). These three tectonostratigraphic units piled one upon the next make up the Morais Massif (Pereira, *et al.*, 1998; 2000).

The Lower Ophiolite Complex comprises a set of thrust-bound slices/scales that are repeated out-of-sequence and overthrust at the base of the Morais Ophiolite Complex (Intermediate Allochthonous Complex). This Lower Morais Ophiolite Complex is made up of the Pombais Unit (Silurian-Devonian in age) and comprises basic metavolcanic rocks with a clear MORB signature that gradually give way to green schists at the top of each thrust slice/scale and represent the first indication of oceanic rifting of the Galiza-Maciço Central Ocean (GMCO), (Pereira *et al.*, this volume).

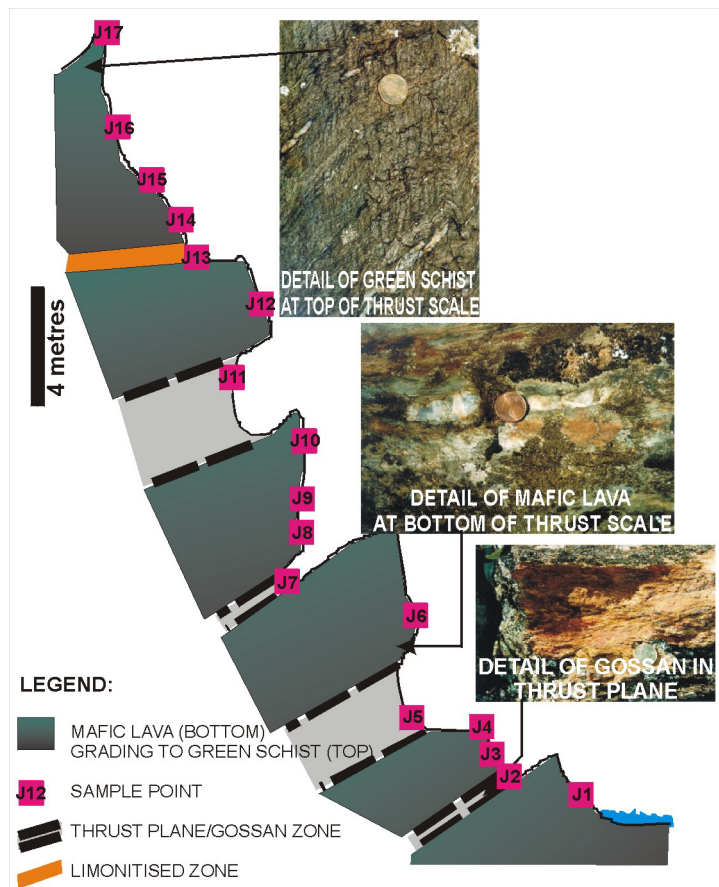


Figure 1 – Idealised cross section of the outcrop of the Pombais Unit WNW of Junqueira showing the litho geochemistry sample points.

The Pombais Unit – Junqueira region

In a minor tributary stream of the Sabor River, situated approximately 1 km WNW of the village of Junqueira (UTM Coordinates: 6-95-889E; 45-95-383N), the Pombais Unit is particularly well exposed.

Here, this unit is made up of four thrust-bound slices/scales in cliffs that measure approximately 20-30 m in height. The profile of these cliffs is made up of a series of harder, jutting out, more competent rock (basic metavolcanic rocks) punctuated by less competent rock (gossan zones) creating an almost regularly stepped-like profile (Fig. 1).

In between gossans the more competent rock is made up of a dark green metavolcanic rock (mafic lava) that gradually grades upwards to a more fissile green schist or a brown schist crenulated by the second Variscan phase of deformation (D_2).

The thrust fault zones are marked by the occurrence of Fe-stained gossans, which vary in thickness from a few centimetres to 10's of centimetres.

Mineralisation – The mafic lavas of the Pombais Unit are characterised largely by the absence of copious quantities of large microscopic sulphide minerals. However, some very small sulphide minerals have been observed. These range in grain size from < 1 to $6 \mu\text{m}$ long and are characteristically euhedral to

subhedral in shape. Often the subhedral nature of the grains is due to embayment-like features on one or more sides of the grain.

Pyrite, wholly replaced, or rimmed, by goethite is common as are small inclusions of chalcopyrite within the pyrite. The chalcopyrite is locally bordered by covellite (Fig. 2). The pyrite is often fractured and broken up and in cases such as these the cracks are lined with haematite.

Limonite is common as smears in several places on the outcrop surface but no sulphides have, thus far, been seen associated with these zones.

The gossans with abundant limonite also have fine pyrite crystals and also the development of supergene malachite and sulphur salts. The malachite is pervasive and more of a stain than actual crystals developed.

Litho geochemistry – The geochemistry of this sequence of rocks outcropping near Junqueira was investigated by collecting samples at the points indicated in Fig. 1 and the results obtained are shown in Table 1.

The results of this exercise are also plotted in Fig. 3 superimposed on the hard rock zones, i.e. Pombais Unit and the Gossan zones. Co, Cr and Ni show limited expression and their distribution throughout the outcrop is erratic although some peaks of these elements coincide with the gossan zones.

Copper peaks are evident above 1500 ppm and coincide closely with gossan zones indicating its mobility along these horizons. The Zn pattern is erratic and near the top of the outcrop the values are less pronounced than at the base of the outcrop.

In terms of precious metals, their content is very low and far outweighed by the base metal content. A few of the samples were chosen for platinum analysis but the results are disappointing. Nevertheless, higher values seem to be accompanied by elevated values in Co, Cu and Ni (Table 1).

Apparent in Table 1 is sample J-13, collected in a friable and limonitised horizon of crenulated schist that is anomalous with respect to all the other samples collected. This sample is highly enriched in As, Nb, Pb and Sb with most of the other element suite not having been detected. The nature of the rock is unsuitable to make a thin section and the outcrop shows no visible minerals that could account for this. Hence, this feature remains enigmatic at the time of going to press.

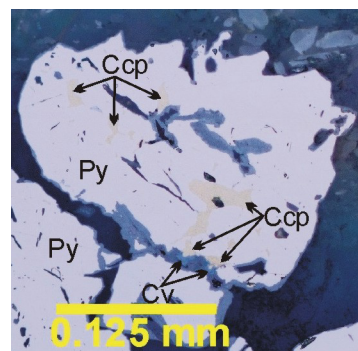


Figure 2 – Detail of pyrite (Py) grain with inclusions of chalcopyrite (Ccp) altered to covellite (Cv). Grey areas are haematite.

Table 1 – Lithochemochemistry results of the Pombais Unit. Sample point location is as per figure 1; na- not analysed; nd- not detected. (Note: Au & Platinoid analyses carried out at Genalysis by fire-assay and ICP-MS, Australia; other analyses carried out at the Laboratory of the IGM, Porto by ICP-MS.

		Ir	Os	Pd	Pt	Rh	Ru	Au	Ag	As	B	Ba	Be	Cd	Co
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm
J-1 lithochemochemistry	J-1	na	na	na	na	na	na	na	<2	<20	<8	48	1	<4	24
	J-2	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	nd	nd
	J-3	nd	nd	2	7	1	3	nd	<2	<20	<8	<25	<1	<4	48
	J-4	nd	nd	nd	nd	nd	3	nd	<2	<20	<8	<25	1	<4	50
	J-5	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	nd	nd
	J-6	na	na	na	na	na	na	na	<2	<20	<8	<25	1	<4	55
	J-7	nd	nd	2	nd	nd	nd	19	<2	28	<8	41	<1	<4	113
	J-8	na	na	na	na	na	na	na	<2	<20	<8	164	1	<4	28
	J-9	na	na	na	na	na	na	na	<2	<20	<8	368	2	<4	<9
	J-10	na	na	na	na	na	na	na	<2	<20	<8	290	2	<4	<9
	J-11	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	nd	nd
	J-12	na	na	na	na	na	na	na	<2	<20	<8	363	2	<4	<9
	J-13	na	na	na	na	na	na	na	nd	13700	nd	nd	2900	nd	204
	J-14	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	nd	nd
	J-15	na	na	na	na	na	na	na	<2	<20	<8	301	2	<4	<9
	J-16	na	na	na	na	na	na	na	<2	<20	<8	318	2	<4	<9
	J-17	na	na	na	na	na	na	na	<2	<20	<8	528	2	<4	<9
		Cr	Cu	Fe	Mn	Mo	Nb	Ni	P	Pb	Sb	V	W	Y	Zn
		ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
J-1 lithochemochemistry	J-1	161	368	6,6	1539	<4	15	37	719	<16	<12	175	<18	45	277
	J-2	179	1700	22,2	732	nd	nd	nd	668	nd	nd	229	nd	194	600
	J-3	259	1025	8	1303	<4	16	79	875	<16	<12	240	<18	127	830
	J-4	234	898	9,3	1569	<4	21	83	1077	<16	<12	299	<18	110	612
	J-5	93	2600	27,7	521	nd	nd	nd	345	nd	nd	208	nd	290	455
	J-6	162	854	8,7	1758	<4	24	67	1558	<16	<12	300	<18	104	765
	J-7	161	820	13,5	682	16	8	37	436	<16	<12	176	<18	98	361
	J-8	201	436	5,2	1488	<4	17	71	654	<16	<12	175	<18	51	503
	J-9	207	474	5	197	<4	14	<13	393	<16	<12	118	<18	56	39
	J-10	110	134	4,1	3124	<4	10	47	385	<16	<12	77	<18	16	106
	J-11	140	1900	16,3	nd	nd	nd	nd	645	nd	nd	190	nd	218	154
	J-12	173	102	3,9	1187	<4	7	40	487	<16	<12	88	<18	12	137
	J-13	nd	nd	nd	nd	nd	4900	nd	nd	87000	85000	nd	nd	nd	nd
	J-14	145	1700	20	nd	nd	nd	nd	674	nd	nd	170	nd	200	103
	J-15	111	421	7,8	219	<4	4	<13	586	<16	<12	95	<18	50	139
	J-16	129	341	5,7	168	<4	6	<13	475	18	<12	106	<18	40	81
	J-17	119	34	4,6	824	<4	8	43	509	<16	<12	115	<18	4	87

Discussion and conclusions

At Junqueira, the observed lithochemochemistry results indicate that the precious, base and transition metal content of the mafic lavas and green schists making up the Pombais Unit is low. However, remobilisation of these metals channelled through the gossan zones separating the thrust scales increases their content many fold. In the case of (average) Cu the increase is 3 fold in the gossan.

Petrographically, the ore mineral assemblage in the Pombais Unit is scarce and erratic. Nevertheless, subhedral to euhedral small pyrite grains, partially or completely replaced by goethite are observed. Chalcopyrite, within the pyrite, and at times replaced by covellite has also been seen. Haematite and goethite (+ limonite) are common minerals given the proximity to prominent gossans.

Supergene malachite and sulphur salts are common in the gossan zones and in the mafic lavas and schist bordering these.

The results obtained in this study show that the feasibility of large-scale hydrothermal activity and remobilisation of metals during the initial stages of rifting that originated the Lower Morais Ophiolite Complex is diminished. However, some later stage hydrothermal activity is apparent and remobilisation has taken place as evidenced by the occurrence of Fe-bearing minerals, Cu-sulphides and Cu-carbonates in the gossans. Investigation continues.

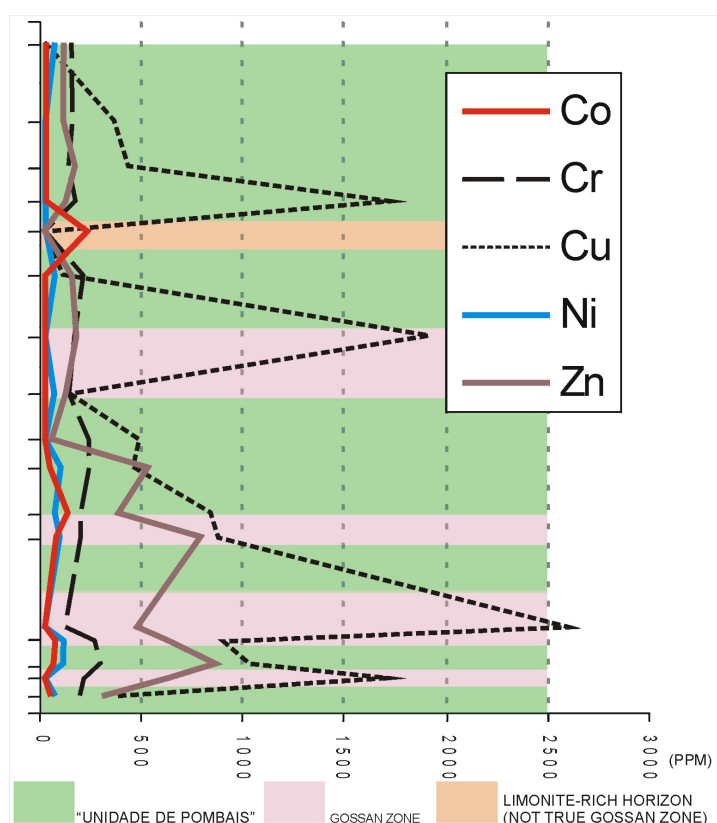


Figure 3 – Graphical results of the analytical results of the Pombais Unit according to the sample points location as per figure 1.

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