sym=078033

A. FIELD EXCURSION POÇOS DE CALDAS

Excursion leader:

H.H. Ulbrich

Instituto de Geociências,

Universidade de São Paulo

Introduction

The Poços de Caldas alkaline massif stretches across the border between the States of São Paulo and Minas Gerais, about 250 km from the city of São Paulo. It crops out over 800 km^2, and is composed almost entirely by feldspar-bearing rocks (phonolites and nepheline syenites, Fig. 1). It is larger in size than most occurrences of its kind (Lovozero, 650 km^2; Pilaanesberg, 570 km^2), with the exception of the Khibina massif (1330 km^2). The district was mapped for the first time, in detail, by R. Ellert, A.J.S. Björnberg, and J.M.V. Coutinho (cf. Björnberg, 1959; Ellert, 1959) and remapped later on (by geologists from the Comissão Nacional de Energia Nuclear, cf. Utsumi et al., 1971; and by H. Ulbrich, 1984).

The massif has a roughly subcircular outline, with a larger N-S diameter (35 km), and a shorter one of about 30 km in the E-W direction. It is limited on its northern, western and southern margin by a pronounced topographic ring of phonolites (up to 1450-1600 m high; "ring dyke", Ellert, 1959), which is absent along the eastern border; a sometimes well-marked depresion -at least in part conditioned by erosion- accompanies the inner part of this ring, separating it from the rest of the massif. The interior presents an irregular topography, where flatter areas (to the north and south) alternate with others which are more irregular (in the central, eastern and western parts); tallest peaks reach here a height of about 1400 m.

Petrography

Main outcropping rocks are hololeucocratic to leucocratic phonolites (either

International Conference = Geochemical Evolution of the Continental Cru
1988, Poços de Caldas. Guidbook.

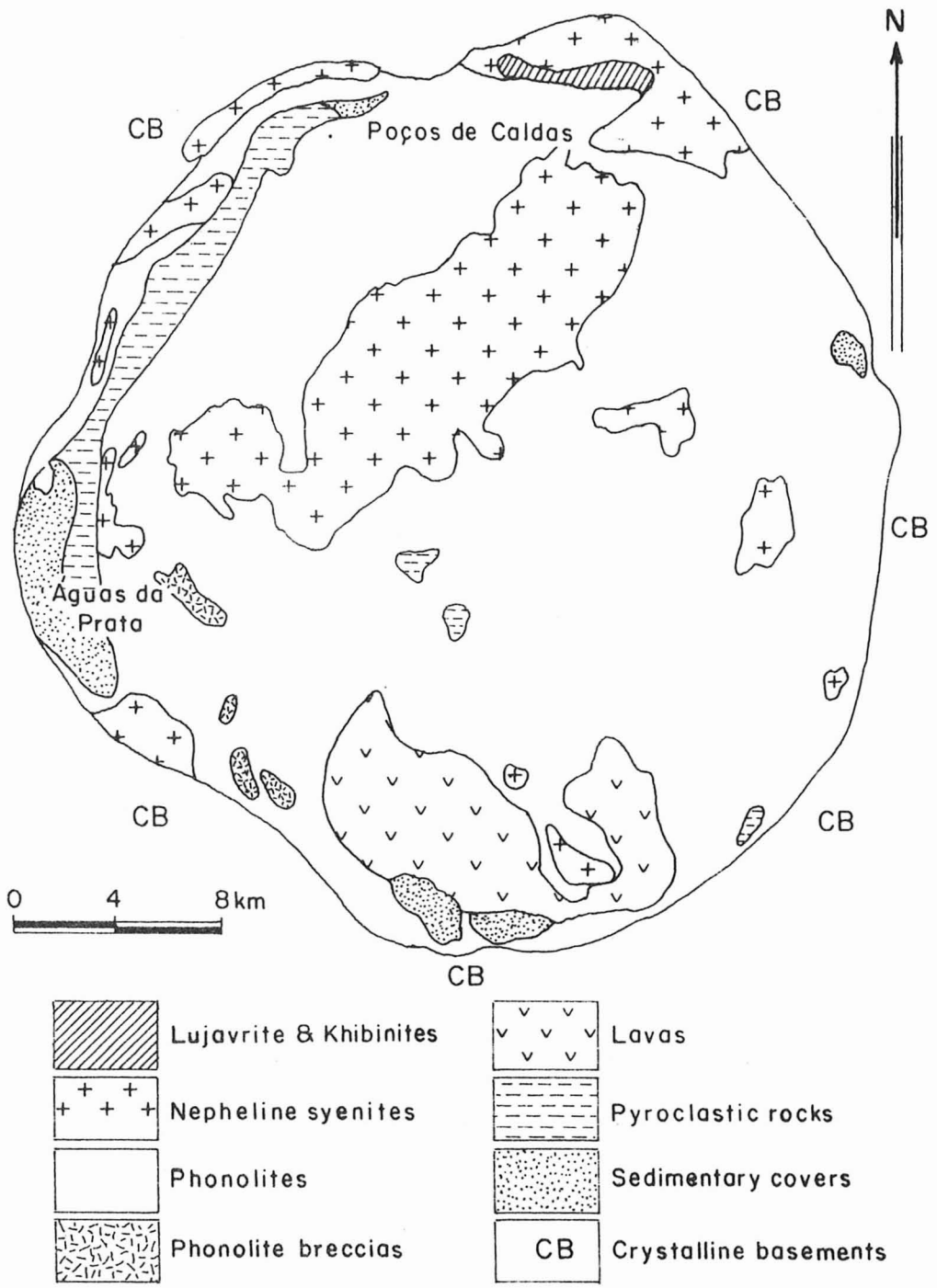

Figure 1 - Simplified geologic map of the Poços de Caldas massif (after R.Ellert, J.M.V.Coutinho and A.Björnberg; cf. Ellert, 1959)

aphyric or, less fraquently, porphyritic varieties of aphanitic to very fine-grained phonolites, as well as fine-grained "tinguaites"; 83% of outcrops) and nepheline syenites (14%, including some smaller ocurrences of khibinites and mesocratic lujaurites). Also found are volcanoclastic rocks (mainly intrusive breccias and agglomerates and widely scattered ocurrences of mostly supracrustal tuffaceous rocks; 2% of outcrops) and cover sandstones belonging to the Jurassic-Cretaceous Botucatu Formation; a sequence of sandstones with intercalated laminated siltstones, representing remnants of the underlying Piramboia Formation, are also observed at the southwestern margin.

Most phonolites are clearly intrusive rocks, probably related to dome or dike intrusions; some of the southern outcrops were interpreted as lava fields (Ellert, 1959). Main minerals are Or-rich K-feldspar, nepheline and Na-pyroxene (aegirine-augite and aegirine, more rarely Na-augite) accompanied by some biotite and a sometimes bewildering variety of rare minerals. Nepheline syenites show a similar mineralogy; although apparently monotonous rocks, they can be easily classified as several facies types, each identified by texture and the presence (or absence) of rarer minerals (one of which, eudialyte, may appear as a rock-forming mineral). In most cases, nepheline syenites invade phonolites; contacts are then always sharp, although larger nepheline syenite bodies may present a distinct "contact zone" (characterized, for instance, by abundance of fine-grained enclaves in a syenitic matrix). There is also ample field evidence that nepheline syenites were invaded by sometimes large quantities of late phonolites.

As well as phonolites, nepheline syenites are conveniently divided into agpaitic and intermediate to miaskitic varieties. The difference is due to chemical variations ("agpaitic coefficient", etc; cf. pertinent literature), but is immediately visible in hand specimens and is thus useful for mapping purposes, on account of the presence or absence of "rare-metal" silicates (e.g., eudialyte, neptunite, astrophyllite, rinkite, lamprophyllite, etc.,all of them characterized by the combination of Na and Ti with other "rare metals" such as Mn, Ti, Zr, Nb, REE, etc., and which form as a result of the relative scarcity of

Al in magmas that are otherwise enriched in alkalies and the cited elements). Detailed mapping showed, in the district, a predominance of intermediate to miaskitic nepheline syenites over agpaitic ones (119 km^2 vs. 25 km^2); a similar relationship probably also holds for phonolites (for data on mineralogy and petrography, especially of nepheline syenites, cf. M. Ulbrich, 1983; H. Ulbrich, 1984; for a summary, see M. Ulbrich et al., 1984).

Ores

Bauxite is the main ore now being mined in the district. Total reserves are probably well over 50 million tons (D.D. Williams, pers. commun.), in part already mined. The ore forms from phonolites and nepheline syenites, both in the interior of the massif (as thinner beds) as well as on the topographic rings (where it is thicker and has the highest grade). Dikes and pods of "caldasite" are found in several areas (e.g., at Morro do Serrote, west-central part of the massif; Cerro Taquari, east-of-center of district; etc.), which is an intergrowth of U-bearing fibrous baddeleyite and small zircon grains; total reserves of the district were estimated at about 100,000 tons. Hydrothermal alteration (mainly yielding the pair K feldspar-illite, with some pyrite, smectite, iron oxides, fluorite, etc.) is a district-wide feature. It is particularly concentrated in an area of roughly circular shape (the "east-of-center circular structure") of over 100 km , which shows, apart from an almost complete hydrothermal alteration of its rocks, also the largest concentration of U-bearing ocurrences; the largest one found up to now, at Campo do Cercado, is currently being mined as an open-pit mine ("Mina Osamu Utsumi" of the state-owned Nuclebrás company), and presents the unusual U-Mo-Zr metallogenetic association. At Morro do Ferro (also located within the mentioned "circular structure"),a large superficial weathering patch is enriched in Th and REE (estimated low- to medium-grade reserves: 1 million tons), placed on top of hydrothermally altered phonolites invaded by magnetite dikes (for a literature review on ore in the district, cf. H. Ulbrich, 1984).

Relative ages and geochronology

Field evidence indicates that most phonolites (mainly as intrusive bodies) were the first rocks to crystallize, followed by most nepheline syenites (intermediate to miaskitic varieties usually precede the agpaitic facies); an unknown amount of late phonolites (but which may be locally very important, such as in the Campo do Cercado mine) invades after the nepheline syenites. Breccias and aglomerates (e.g., in the Vale do Quartel area, and at the Utsumi mine) are mostly later than most intrusive rocks (cf. H. Ulbrich, 1984; Motoki, 1987); supracrustal tuffaceous rocks may also be related to late pyroclastic eruptions. Hydrothermal alteration (plus attendant U-Mo-Zr and caldasite mineralizations) are late phenomena, clearly related to the last pyroclastic eruptions.

Earlier K-Ar geochronology (Amaral et al., 1967; Bushee, 1971) indicated a wide age span, from about 90 Ma for some pyroxene-bearing mafic breccia clasts, up to about 56 Ma for a late phonolite dike (cutting nepheline syenites). Rb/Sr isochrons on two genetically related nepheline syenite groups (lujaurite-khibinite and nepheline syenite dike rocks of the northern ring area) show ages of 86 and 89 Ma (Kawashita et al., 1984); the figure of 89 (± 2) Ma is preferred by the author for age (and age interval) of the entire massif, for several reasons (H. Ulbrich, 1984).

References

Amaral, G., Bushee, J., Cordani, U.G., Kawashita, K., Reynolds, J.H. (1967) Geochim. Cosmochim. Acta, 31:117-142.

Bushee, J. (1971) Ph.D. thesis, Dept. Geol. Geophys., UC Berkeley, 145p.

Björnberg, A.J.S. (1959) Fac. Fil. Ci. Let. - USP, Bol 237, Geol. 18:5-63.

Ellert, R. (1959) Fac. Fil. Ci. Let. - USP, Bol 237, Geol. 18:5-63.

Kawashita, K., Mahiques, M.M., Ulbrich, H.H. (1984) XXXIII Congr. Bras. Geol., Rio de Janeiro, Breves Comunicações, p.244.

Motoki, A. (1987) An. IV Simp. Geol. Minas Gerais, Belo Horizonte, p.420-433.

Ulbrich, M.N.C. (1983) Ph.D. thesis, Inst. Geoc., Univ. São Paulo, 369p.

Ulbrich, M.N.C., Gomes, C.B., Ulbrich, H.H. (1984) XXXIII Congr. Bras. Geol.,Rio de Janeiro, Anais, 9:4362-4376.

Ulbrich, H.H. (1984) "Livre Docência" thesis, Inst. Geoc., Univ. São Paulo.

Utsumi, O., Oliveira, A.G., Parisi, C.A., William, D.P. (1971) XXV Congr. Bras. Geol., São Paulo, Rot. Excursões, Bol. Esp. 2:7-13.

Road stops (Fig. 2).

Stop 1. Panoramic view of the massif. From the "Cristo Redentor" statue, a vista point, the entire outline of the massif can be observed on a clear day. To be pointed out: topographic ring of phonolites (to the south, west and north), and its absence to the east; topography of the interior of the massif; areas with nepheline syenites, pyroclastic rocks, and hydrothermal alteration, and their geologic significance. Intrusion model ("caldera" vs. "dome) will be discussed.

Stop 2. The lujaurite-khibinite body at the "Pedra Balão" ("balloon rock"). Outcrop of stratiform nepheline syenites. Structural position is as follows (from center to periphery): a) coarse-grained lujaurite (foliated mesocratic eudialyte nepheline syenite, with fibrous aegirine and the structure of a gneissic rock); b) finer-grained lujaurite; c) two facies of trachytoid leucrocatic to hololeucocratic nepheline syenites (with little eudialyte, and oriented tabular K-feldspar and prismatic aegirine); d) khibinite (massive leucrocatic eudialyte nepheline syenite with large poikilitic platy aegirine). The whole body (1.5 km^2) is intrusive into border nepheline syenites and phonolites; a somewhat larger independent body (same stratigraphy) crops out farther east. Structure, petrography and mineralogy will be observed and discussed.

Stop 3. Prefeitura quarry. A quarry owned by the City of Poços de Caldas, cut into the so-called "Pedreira" nepheline syenite facies. Shown is the northernmost contact zone of this large intrusion (intrusions?), covering over 80 km^2. The contact zone is characterized by petrographic inhomogeneity and presence of sometimes large amounts (up to 30-50% of outcrop) of fine-grained rounded phonolite enclaves (1-2 cm to over 30 cm). The quarry shows also a

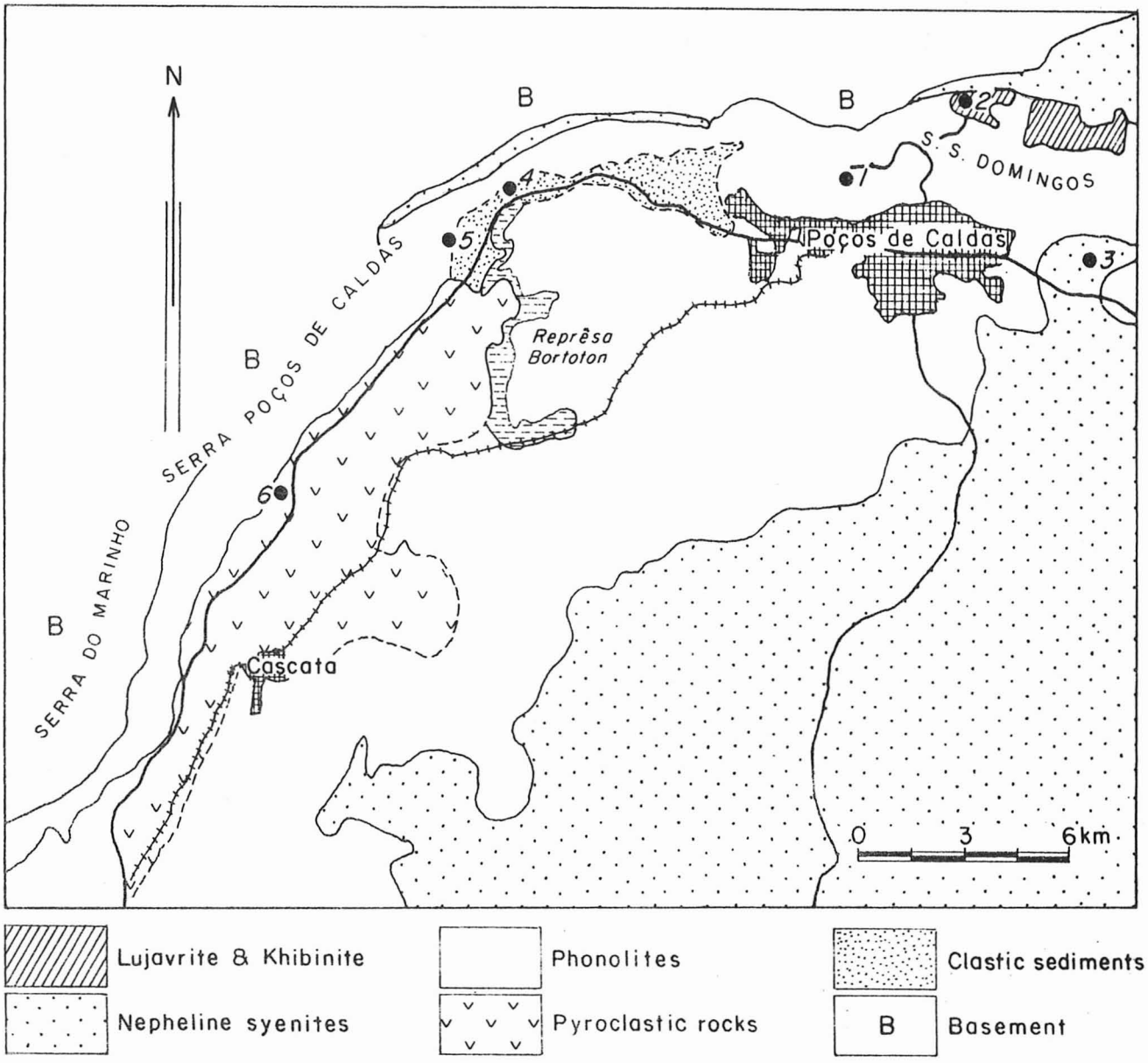

Figure 2 - Road stops, Poços de Caldas massif (cf. text).

meter-sized aphanitic to porphyritic phonolite dike, laterally thinning out into a final intrusion wedge. In geodes and along fracture zones, an interesting variety of minerals is shown: aegirine, natrolite, analcime, calcite, eudialyte, greenish-violet fluorite, pyrite, ilmenite, kutnahorite. Petrography and intrusion mechanisms of rock types will be discussed.

Stop 4. Sandstones (mainly, quartz arenites) of the Botucatu Formation. Very poorly indurated sandstones (medium to coarse-grained), showing clearly large-scale cross-bedding (a typical feature of the aeolian Botucatu sandstones, deposited in the very large Jurassic or Early Cretaceous pre-basaltic "Botucatu desert", which covered well over 1.5 million km^2). The sandstones are quarried for their quartz content. The situation of the cover sandstones, in the district, will be discussed, and its possible use for defining the intrusion model for the Poços de Caldas massif.

Stop 5. Bortolan quarry. A privately owned quarry cut into various phonolites of the eastern topographic ring. Textures and structures of the rocks vary rapidly, and show (along fractures and in geodes) several late minerals: eudialyte, aegirine, K-feldspar, natrolite, calcite, analcine, rinkite, astrophyllite, pyrrhotite, violet fluorite, Mg-palygorskite (?), villiaumite, strontianite, several clay minerals. As in the Pedreira quarry, these minerals crystallized in a clearly defined age pattern (kaolinite and some montmorillonites, for instance, were deposited on late fractures). Textural variations of the phonolites and the pattern of late crystallization of differentiated minerals will be discussed and compared with that observed in the Prefeitura quarry.

Stop 6. The agglomerates and breccias of the pyroclastic "belt" of the Vale do Quartel. The valley is cut into a large N-S directed belt of agglomerates, breccias and tuffaceous rocks, which develops between the western topographic ring and the Serra do Quartel, both constituted by massive largely aphyric phonolites. Petrography and structure of the deposits will be observed, and its age relationship with the surrouding rocks will be discussed.