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The nonmetallic and combustible deposits and manifestations scale 1:500,000 previously prepared by the Institute. For the expression of the raw materials, special symbols are used: the form of the symbol expresses the genetic type; the abbreviations explain the type of the raw material, while the color inside the symbol distinguishes the main usage. Two sizes of the symbol are used: the greater one for the deposits, the smaller one for the expression of the manifestations. The item situated on the corner of the symbol makes it possible to find more information about the typical deposit in the explanation part of the map.

The minerogenic analysis of the country has been realized by the form of minerogenic regionalization of structural-formational basis, taking out a system of the minerogenic zones and subzones. The minerogenic zones are taken out from the structural-formational complexes, while the subzones are separated from the geologic formations. In both minerogenic units, the outlines are expressed by means of different colors and graphic forms of the lines. For the verified areas, the lines are in solid while for the supposed areas interrupted lines are used. For the expression of the minerogenic charge of each zone and subzone, the abbreviations of the raw materials are used (the same as in the symbols of raw material deposits), situating them inside the border of the zone or subzone. To distinguish the syngenetic and epigenetic type of the mineral, two forms of letters are used: boldfaced and regular weight.

The explanation part of the map includes the scheme of the geologic complexes and formations with the general view about all principal aspects of the country's regionalization. In this scheme, the typical raw materials presented in different zones and subzones are expressed by the same abbreviations of raw materials as in the map.

Special attention has been paid to the development of the young deposits in the Plio-Quaternary period, for the reason that because of intense weathering processes in Cuba, there is a high number of useful deposits in the altered and redeposited rocks that have not been sufficiently explained by the traditional form of the geologic map.

The main purpose of this minerogenic map is to serve to the nonmetallic raw materials prognostic maps to different scales; to give perspectives and general directions for the orientation of the strategy and the tactics of the geological prospecting labors, to be used as consulting material for all specialists of the geological branch and of the institutes related, and finally to offer data of reference and comparison of the minerogenic studies of the territories located on the tropic and subtropic zones and more specifically in regions of active or extinct volcanic island arcs.

COUTINHO, J. M. V., and M. L. LAZZARI, Universidade de São Paulo, São Paulo, Brazil

#### Petrology of Proterozoic Volcano in São Paulo, Brazil

The early Proterozoic (1800 m.y.) São Roque schist belt, 200 km long and 20 km broad, runs east-northeast-west-southwest and abuts the northern outskirts of São Paulo City. It consists of metapelitic rocks (phyllites and mica schists) and subordinate amounts of quartzite, metasandstone, metaconglomerate, metabasitic, carbonatic, and calcisilicatic rocks. The belt is speckled by many synkinematic granitic intrusions, some of them attaining batholithic dimensions. Transcurrent dextral faults mark its north and south limits against gneiss-granitic terrains.

Inside the schist belt, a lower stratigraphic unit—the Itaberaba volcano-sedimentary sequence—is enriched in metabasic components. Pirapora do Bom Jesus (PBJ) is one locality 30 km northwest of São Paulo where greenstone outcrops show at its best the evidences of a basaltic volcanism. In spite of a commonly deep weathering and deformation in at least three stages that frequently obscure primary features, it was always possible to observe isolated structured expositions and to collect a number of fresh samples for chemical and microscopic analyses. As a matter of fact, in road cuts in and near PBJ, pillow structures are even enhanced by moderate weathering.

The PBJ greenstones make up what seems to have been a Proterozoic tholeiitic volcano or volcanic complex. Its deformed and metamorphosed equivalent covers a 1.5 × 3.0 km elliptical area at the crest end of an east-northeast-plunging low-angle syncline. The PBJ volcano is surrounded by clastic metasedimentary rocks whose strata define the fold limbs. Two additional metabasitic areas, a large one outcropping along the fold axial plane and a smaller one at the outer crest, seem to outline other not yet studied volcanic centers.

Geological survey in the PBJ volcano makes it likely that its former horizontal base did not change more than 30° during deformation, folding, and metamorphism. The Tietê river rapids cut the structure from northeast to southwest through its center. At this point, the river bedrock is an assemblage of disordered greenstone bodies probably representing a swarm of sills and feeding dikes. Over it lies a succession of somewhat inclined lava flows with pillows in way up position. Some features described: arched upper surface, downward-pointing protrusions, brown "palagonitic"

rims, radiating cracks, peripheral radial pipe vesicles (2 mm thick), textural and mineralogical variations, etc. On top of the pillow lava flows occurs a pile of entirely weathered banded material formed by greenstones evolved, presumably, from interbedded tuffs, breccias, and flows. At the border line of the PBJ greenstone area, several carbonatic occurrences have been mapped. Some of them expose stromatolitic structures printed in breccia fragments.

Modal analyses in 10 PBJ greenstone samples of indiscriminate derivation (flow, sill, or dike) gave the following averages and ranges: actinolite, 37.5 (28–46); albite, 23.5 (16–32); epidote, 20.0 (8–32); chlorite, 12.5 (5–21); titanite, 3.5 (3–5); calcite, 1.5 (0–5); biotite, quartz, pyrite, and hematite in minor amounts (<1). With such compositions, the greenstones can be petrographically described as chlorite-epidote-albite schists (if schistose) or fels (if massive). They are mostly fine grained, thus reflecting somewhat the former basaltic grain size. Intrusive dikes and sills may be coarser grained. Unoriented felty or decussate textures are common, but nematoblastic, porphyroblastic, and blastoporphyrific textures are also found. The basic rocks underwent phases of deformation during low-grade regional metamorphism, but structures and igneous textures have been partially preserved.

Five thin sections were also made in an individual 21 m large, semi-weathered pillow. The microscopic study showed that the former palagonitic crust is now transformed into a clay-limonite-epidote mass, the epidote blasts replacing shards and preserving small-scale banding. Internally, the metamorphic assemblage is actinolite-rich in the slightly schistose and crenulated border zone and more albitic in the coarser massive core samples. It may be inferred that the basaltic pillow cores should have been somewhat "spilitic" (high in Na<sub>2</sub>O, low in CaO and MgO) as compared with the rims (lower SiO<sub>2</sub>, Na<sub>2</sub>O, higher Fe, MgO, CaO).

Chemical analyses in the foregoing 10 PBJ samples furnished the average and range results: In %: SiO<sub>2</sub>, 48.2 (45.9–50.5); TiO<sub>2</sub>, 1.39 (1.18–1.53); Al<sub>2</sub>O<sub>3</sub>, 14.6 (13.8–15.4); total Fe as FeO, 11.1 (10.51–11.94); MnO, 0.14 (0.11–0.15); MgO, 8.0 (7.07–9.47); CaO, 9.8 (7.14–12.33); Na<sub>2</sub>O, 1.88 (1.66–1.99); K<sub>2</sub>O, 0.41 (0.30–0.66); I.L., 3.35 (2.50–4.42). In ppm: Cu, 173 (80–239); Ni, 189 (167–215); Co, 111 (80–120); Cr, 166 (117–263).

The average major element composition, after correction for I.L., compares well with oceanic tholeiites. Selected elements when plotted in convenient diagrams (Pearce, 1975; Pearce et al., 1977) indicate that the PBJ metavolcanics evolved from seafloor tholeiitic basalts probably raised in an ocean island. Geological and petrographical data shape of the body, stromatolitic talus fragments, distribution and size of pillow vesicles are suggestive in that the body was once a submarine volcano emerged, in warm waters, from depth shallower than 700 m.

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- Nickel and Molybdenum-Rich Black Shales of Southern China: New Ore Type with Possible Analogues in the Pennsylvanian of the USA
- Since 1985, a Ni-Mo deposit located near Songlin near Zunyi, Guizhou, China has been mined for molybdenum. Ores occur in a 2 m thick horizon of black shale containing a 5–15 cm nodular Ni- and Mo-rich sulfide lens which averages 2–4% Mo, but also contains up to 4% Ni, 2% Zn, 0.7 ppm Au, 50 ppm Ag, 0.3 ppm Pt, and 30 ppb Ir (Chen et al., 1982; Fan, 1983; Fan et al., 1984; Chen, 1988; Chen and Coveney, 1988). Although the Songlin mine currently produces only 1000 tons of ore per year, the deposit is noteworthy as the only one in the world from which Mo is recovered from black shale. Tailings are stockpiled for future recovery of Ni and precious metals.
- Metal-rich Cambrian black shales occur in nine other provinces in southern China (Chen et al., 1982). For example, ~350 km east of Songlin, in Hunan, Cambrian shales contain similar nodular Ni- and Mo-sulfides with enrichments of Pt group elements (Fan, 1983). Nodular textures, noted by Fan (1983) and other factors imply that submarine hydrothermal springs related to basement faults deposited metals during sedimentation (Chen, 1988). The Cambrian deposits of China were only discovered in the 1970's and possibly similar deposits have been overlooked elsewhere. For example, the extensive Mo-rich shales in the Pennsylvanian of the midwest-