RECONNAISSANCE GEOLOGIC STUDY OF THE VAZANTE ZINC DISTRICT, MINAS GERAIS, BRAZIL

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The project report series presents information resulting from various kinds of scientific, technical, or administrative studies. Reports may be preliminary in scope, provide interim results in advance of publication, or may be final documents.

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ABSTRACT

The Vazante district, Minas Gerais, 130 km south of Paracatú, produces nearly all of Brazil's zinc metal. The district is situated on the western side of the Late Precambrian Bambuí basin and along the eastern and leading edge of the north-trending Brazilian orogenic belt (ca. 600-500 m.y. old) that borders the western margin of the basin. Reconnaissance study indicates that bedding and low-angle thrust faulting, folding, and low-grade metamorphism dominated the structural development of the district. The structural trend within the district is northeasterly, and dips 20°-45° NW. Three sets of folds developed during the main period of eastward thrusting of older Precambrian rocks over the western margin of the Bambuí basin. A fourth fold set is transverse to the regional trend.

The rocks in the district are tentatively assigned to the Paraopeba Formation of the Bambuí Group and are designated A through C in ascending order. Unit A is phyllite to phyllitic siltstone. Unit B consists of interbedded dolomitic lime-stone and marl-limestone. Irregularly distributed limestone ledges 20 to 100 m thick have the appearance of boudins. Their origin is attributed to a combination of rapid lateral facies changes and differential movement at different structural levels along bedding and low-angle thrust faults, with the formation of tear faults vertically limited by the thrust faults. Unit C consists of interbedded siltstone, dolomitic limestone, and sandstone. Phyllitic rocks along member interfaces in units B and C and at the base of unit C indicate differential penetrative

deformation and bedding faulting. The contacts between units A, B, and C are interpreted to be low-angle or bedding faults, and their original stratigraphic positions with respect to each other is unknown.

Zinc silicate minerals (hemimorphite and willemite) occur in a folded breccia zone in the lower part of unit B. The breccia zone is interpreted to be tectonic in origin, having formed along the step of a step-bedding-plane fault during the Brazilian orogeny. The zinc is probably syngenetic, and ore deposition in the breccia may have occurred during Brazilian time. Broad uplift and deep weathering of the region took place during late Mesozoic and Cenozoic time. Reserves may be as high as 3 million tons of zinc metal.

INTRODUCTION

The Vazante zinc district, the largest zinc-producing area in Brazil, is approximately 130 km south of Paracatú and 120 km northwest of Patos de Minas in the western part of the State of Minas Gerais (fig. 1). Two companies are operating in the area, Companhia Mineira de Metais at Serra do Poço Verde and Companhia Mercantile Industrial Ingá at Serra do Ouro Podre (fig. 2). They had produced approximately 75,000 metric tons of zinc metal from 1965 to 1973 (White and Nagell, 1975).

The purpose of our investigation was to prepare, using photogeologic techniques and limited field reconnaissance, a geologic map of the Vazante region, to provide a better understanding of the regional structural geology, and to serve as the geologic base for a pilot geochemical study of the Vazante district. This pilot study is the initial phase of Projeto Bambuí, a reconnaissance geochemical exploration program of the Bambuí basin undertaken by the CPRM (Companhia de Pesquisa de Recursos Minerais) for the DNPM (Departamento National da Produção Mineral). This report was prepared as part of the cooperative program of the Ministry of Mines and Energy and the U.S. Geological Survey (USGS), sponsored by the Government of Brazil and the Agency for International Development, U.S. Department of State, under PASA no. LA (IC) 30-68, Loan no. 512-L-065.

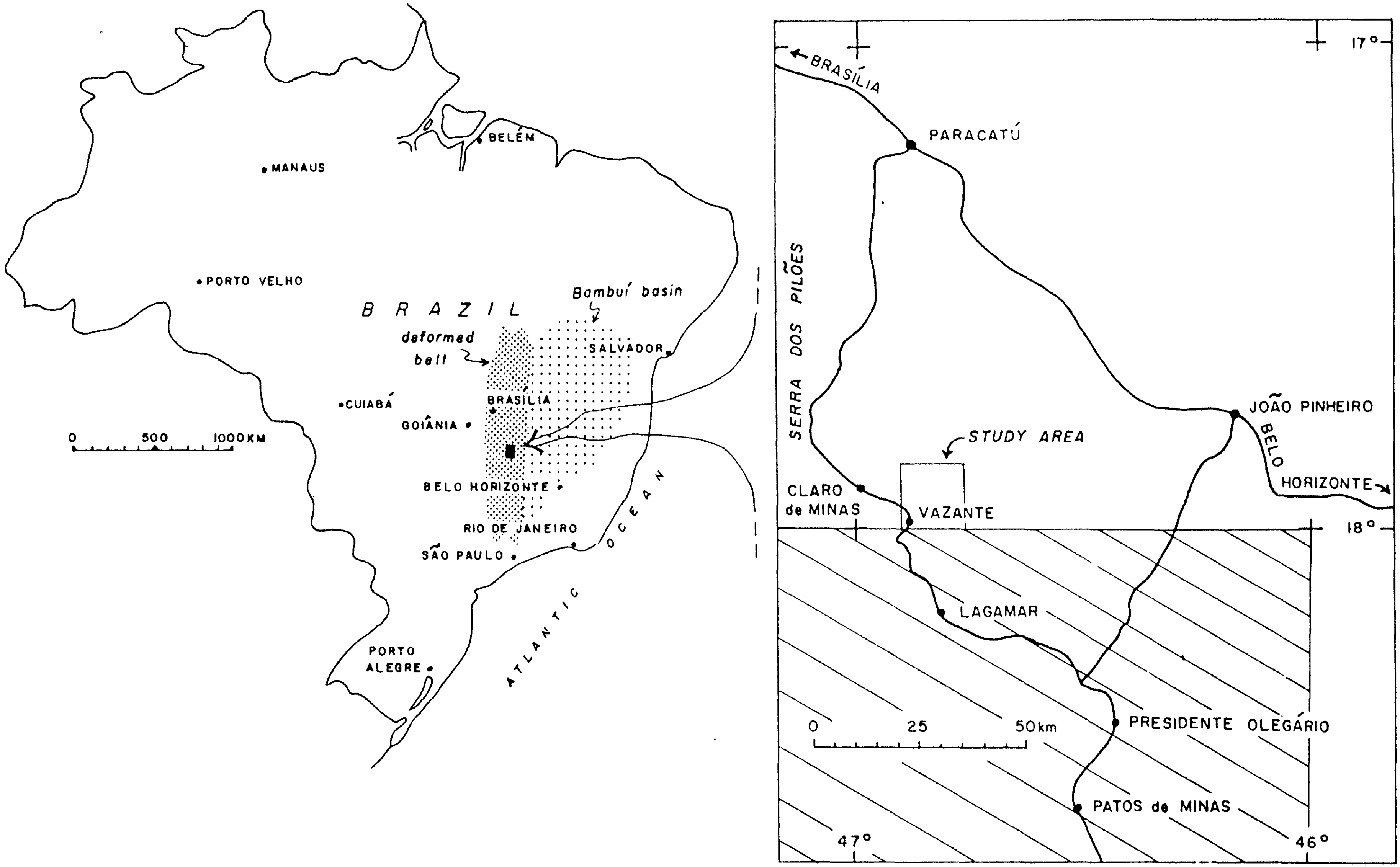


Figure 1. Index map of Brazil and the Vazante region. Ruled part is area studied by Barbosa and others (1970).

Acknowledgments

We wish to acknowledge the many fruitful discussions with Dr. Oscar P. G. Braun that helped us develop our thoughts and ideas on the geology of the region. The aid of Dr. Benedito P. Alves, Chief of the CPRM Agency in Belo Horizonte, in obtaining field vehicles and support was especially appreciated. Drs. Carlos Alberto Heineck and Hugo Peter Steiner, from the CPRM Belo Horizonte Agency, took part in our field work and their assistance is gratefully acknowledged. Dr. Percio Branco made several pertinent, helpful suggestions during the final preparation of the manuscript. We especially acknowledge the support of Dr. Batista de Vasconcelos Dias, CPRM Director and Coordinator of the MME/USAID Agreement.

Historical background and previous work

The discovery of zinc in the Vazante area is attributed to Sr. Angelo Solis, a local farmer, merchant, and amateur prospector, who, in 1952, found hemimorphite (calamine) along the "mineralized cuesta" (see below) along the Serra do Poço Verde (fig. 2). In 1954 Sr. Solis showed the area to Sr. Alberto Velasco, who obtained an option for the mineralized area and later transferred it to the Companhia Níquel Tocantins, of the Votorantim Group. The Companhia Mineira de Metais was formed by the Votorantim Group to operate at Vazante. Later the Companhia Mercantil e Industrial Ingá obtained a concession on Serra do Ouro Podre. Companhia Ingá commenced production in 1965 and Companhia Mineira de Metais began in 1970.

In 1955 Luciano Jacques de Morais presented the first study of Vazante and in 1956 S. L. Moore, of the USGS, studied the Serra do Poço Verde. Subsequently, Carvalho and others (1962), Branco (1962), Guimarães (1962), and Cassedane (1968) reported on the Vazante deposit. These studies were restricted primarily to the deposit, and the narrow cuesta along which mineralization occurs. Amaral (1968) was the first to map the surrounding terrain.

Methods of investigation

We spent approximately three weeks working with 1:25,000-scale aerial photographs to prepare a photogeologic map (figs. 2 and 3). Two trips to the area in March and April, 1974, totaling 5 days of field work, were undertaken to check the photogeologic interpretations and to become familiar with the area.

Several local names for individual parts of the main cuesta near the base of unit B (subunit B-3) along which mineralization took place are shown on the geologic map. We are not aware of any single name that applies to the entire cuesta. For ease of reference we have adopted the informal term "mineralized cuesta" to refer to the entire feature.

REGIONAL SETTING

The study area is in a deformed belt (fig. 1) along the western margin of the Bambuí basin, a late Precambrian basin (1,000 to 600 m.y. old) filled with siltstone, marl, conglomerate, sandstone, limestone, and dolomite of the Bambuí Group. The clastic and pelitic rocks were derived from a highland west of the deformed belt. Older Precambrian rocks were thrust eastward over the western edge of the basin during the Brazilian orogeny (ca. 600-500 m.y.), forming a major north-trending deformed belt about 1,000 km long, characterized by low-angle thrust faults, bedding-plane faults, large folds, and widespread low-grade metamorphism. Allochthonous rocks in the belt include the following Precambrian units, in ascending order (after Barbosa and others, 1970); granite-gneiss complex; mica schist, quartzite, and amphibolite of the Araxá Group; quartzite and phyllite of the Canastra Group, and calcschist of the Ibiá Formation, a basal unit of the Canastra. The Vazante area is about 30 km east of the Serra dos Pilões where the easternmost major thrust brings Canastra over the Bambuí (fig. 1). Smaller-scale thrusting and broad folding of the deformed belt extend to about 100 km east of Vazante. Only the Bambuí Group is present in the study area.

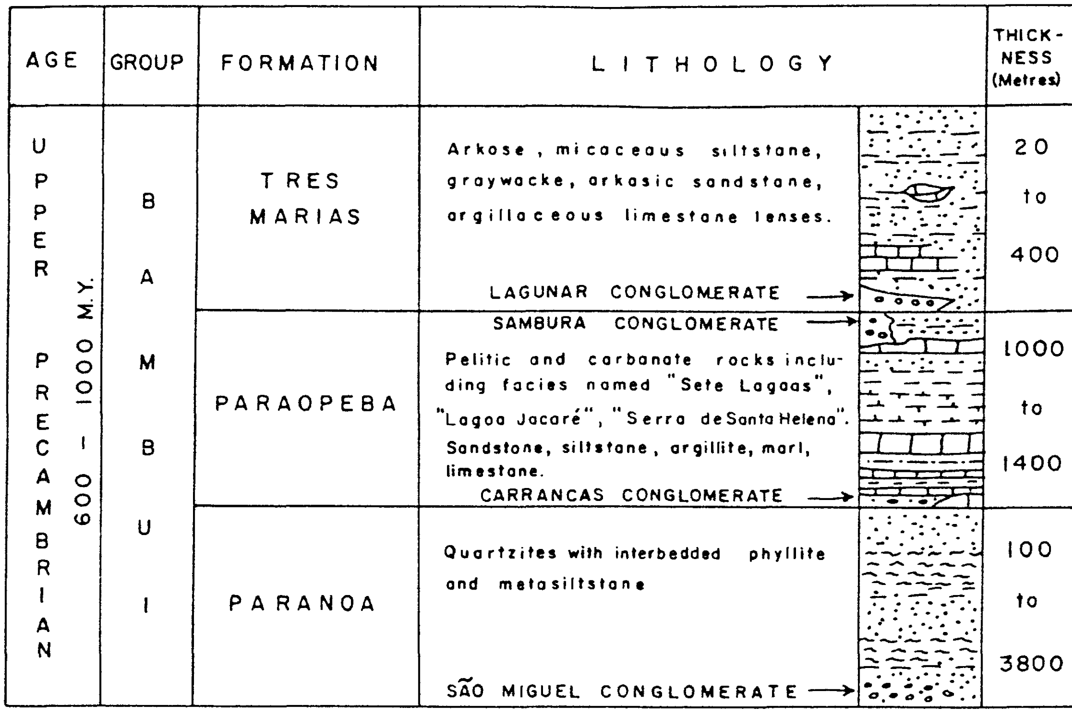
Previous workers interpreted the structural setting at Vazante as being one of normal faulting or tensional tectonics. A plausible alternative presented here involves compressional tectonics with essentially no normal faulting, but with thrust, bedding, and step-bedding faulting and related structural complications consistent with the structural environment of the deformed belt within which the Vazante district is located. Barbosa and others (1970) describe similar structures in the Triângulo Mineira immediately to the south of Vazante (fig. 1).

DESCRIPTION OF GEOLOGIC UNITS

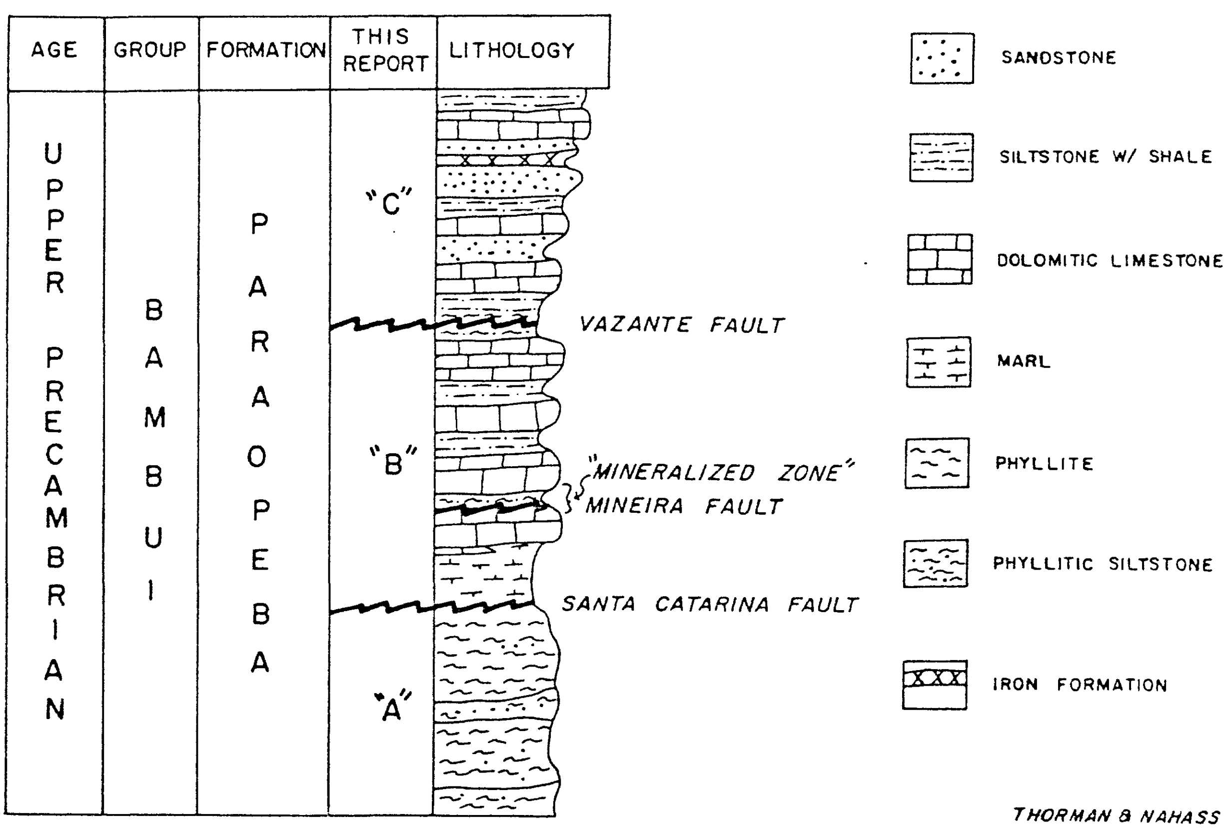
Braun (1968; and oral commun., 1974) considers the entire Vazante region as being underlain by the Paraopeba Formation of the Bambuí Group; Amaral (1968) considered the eastern two-thirds of the area to be underlain by the Sete Lagoa Formation of the Bambuí Group and the western one-third by the Canastra Group. This report follows the work of Braun and divides the Paraopeba Formation into three informal units (A, B, and C, in ascending order). Figures 4a and 4b are diagrammatic stratigraphic sections of the Bambuí Group of the eastern side of the Bambuí basin and of the Paraopeba Formation in the study area.

The relative stratigraphic positions of units A, B, and C are not clear at this time. The contact between units A and B, the Santa Catarina fault, is based on the marked contrast between the pronounced and pervasive penetrative deformation and low-grade metamorphism of unit A and the generally locally developed penetrative deformation and much more weakly developed low grade metamorphism of unit B. Beds on opposite sides of the Santa Catarina fault are more or less concordant. The contact between units B and C, the Vazante fault, is less clear. Along the southern half of its exposure, beds are commonly discordant on a small scale across the contact, whereas beds are concordant across the contact to the north. There is not a pronounced lithologic contrast across the Vazante fault, although sandstone is dominant over limestone in unit C and limestone is dominant over sandstone in unit B.

The Vazante fault is here interpreted as a bedding fault that locally has developed discordant relationships, thus implying that unit B is older than and grades upward into unit C. In contrast, the Santa Catarina fault appears to be a larger structure and the relationship between unit A and units B and C is open to question.



4 a.



4b.

Figure 4. Diagrammatic stratigraphic sections. a, Stratigraphic section of the Bambui Group for the eastern side of the Bambui basin (Braun, 1968). b, Stratigraphic section of the Paraopeba Formation in the Vazante district.

Unit A

Unit A is dominantly a silty micaceous phyllite with thin lenses of quartzite. The phyllite ranges in color from tan to brown to reddish yellow; the quartzite beds are cream colored and have dark red-brown iron-oxide coatings. The rocks are commonly laminated (figs. 5 and 6). A moderate to well-developed foliation at 20° to 90° to the bedding is typical and has often been misidentified as bedding. Fracture cleavage and incipient foliation at 20° to 40° to the bedding are common in the quartzite lenses (fig. 7). Lineations and small-scale folds are common (fig. 8). Thickness of the unit is unknown, but it probably exceeds 500 m.

Unit B

Unit B forms a sinuous northeast-trending belt that ranges in width from 5 km in the southwest to 2 km in the northeast. The dominant lithology is massive to medium-bedded, cream-colored to light gray, aphanitic to fine-grained dolomitic limestone (fig. 9). Collenia occurs in some beds, and siliceous layers are locally present. A few thin beds of medium-grained, well-sorted, light-colored quartzite were noted near the crest of Serra do Poço Verde. Interbedded with the limestone are thin-bedded, in part laminated marl, shale, and siltstone that range in color from red to buff to brown to green.

The massive to thick-bedded limestone underlies cuestas and isolated hills that alternate with elongate and irregular-shaped valleys underlain by marl, shale, siltstone, and in some places, limestone (figs. 10 and 11). This topography is typical of unit B. A major characteristic of the Paraopeba Formation is the rapid lateral and vertical facies change from carbonate to argillaceous rocks (Braun, 1968). A major problem in understanding the geology of the Vazante area is deciphering the relationship of limestone hills to shale and marl valleys that are on strike with the hills. At several localities a 50-80-m section of limestone will change along strike to a comparable thickness of shale in less than 20 m. In a small pit about 2 km south of the Ingá mining

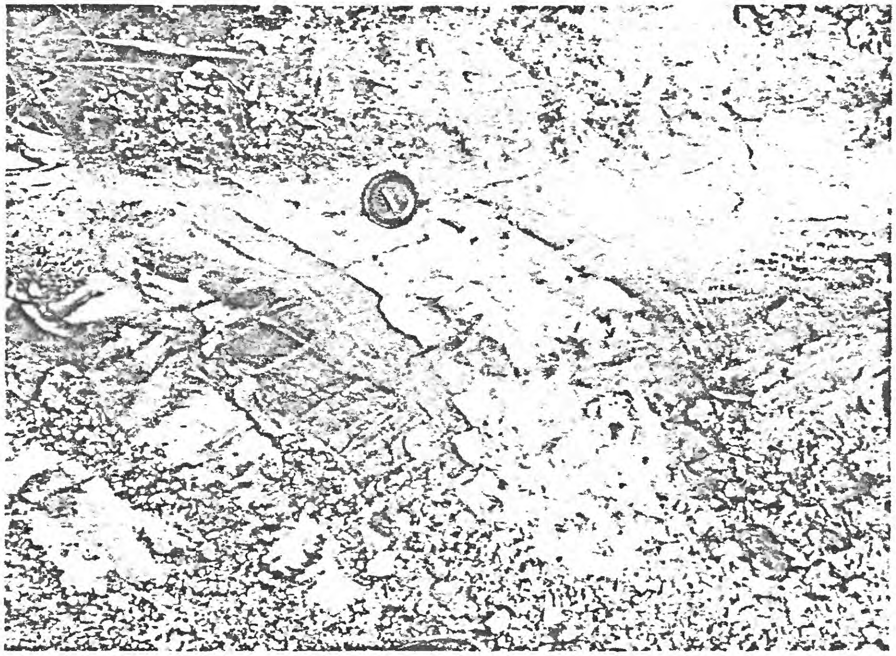


Figure 5.--Thin-bedded, folded argillaceous phyllite of unit A. These are f_1 folds. Note incipient development of foliation along axial planes.

Figure 6.--Faulted, very thin bedded argillaceous phyllite of unit A.

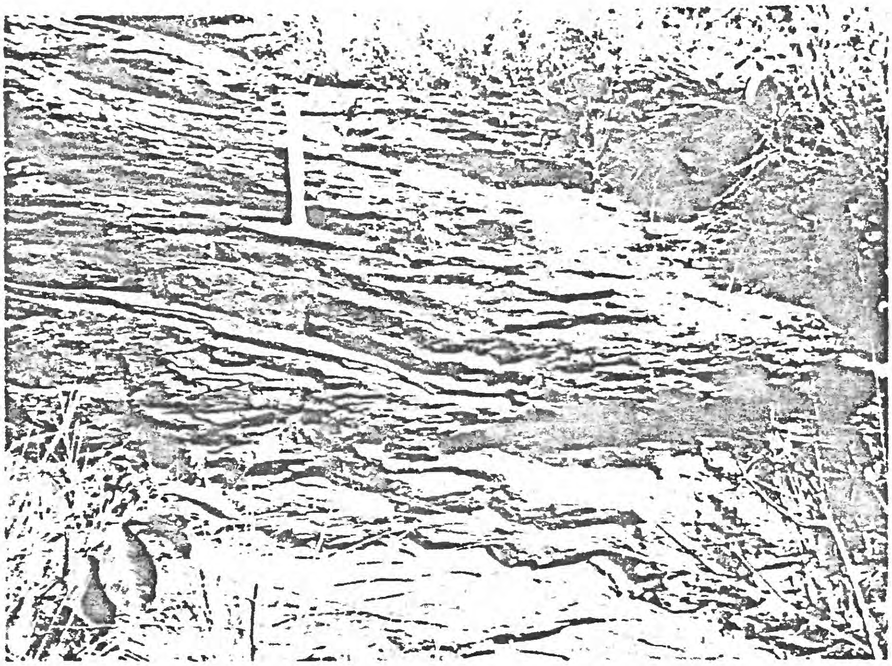


Figure 7.--Resistant fine-grained quartzite interbedded with phyllite of unit A. Bedding is parallel to head of rock hammer. Note incipient foliation and fracture cleavage at 20° to 40° to bedding.

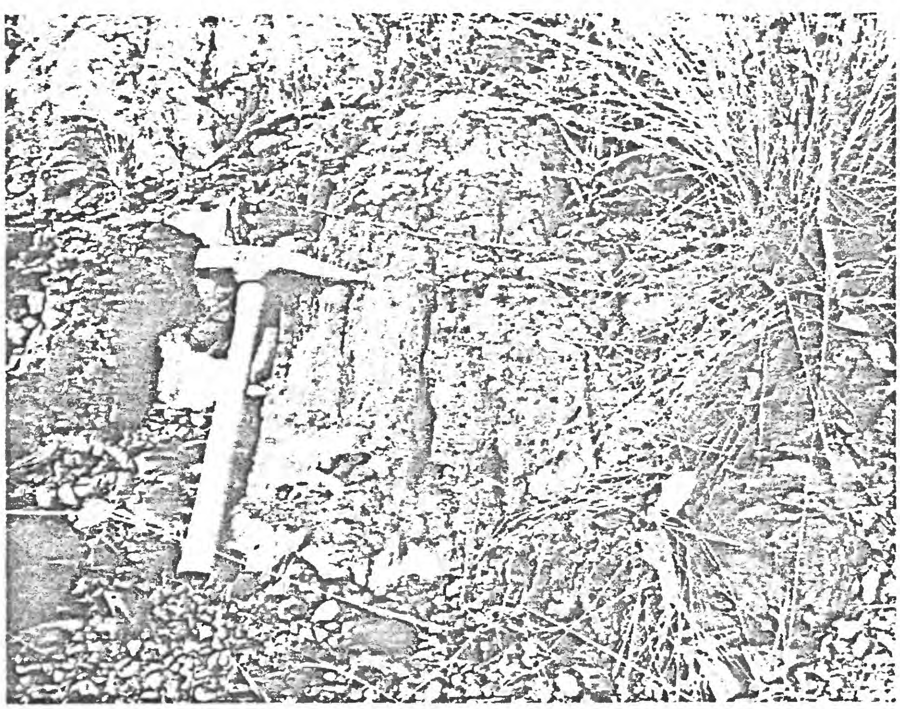


Figure 8.--Small-scale f_1 folds in phyllite of unit A. Fold axes are parallel to handle of rock hammer.

Figure 9.--Thick-bedded dolomitic limestone at the base of subunit B-3 at the south end of Serra do Poço Verde. Dark band near the top is chert.

Figure 10.--Gently dipping thin- to medium-bedded limestone of unit B underlying cuesta southeast of Vazante.

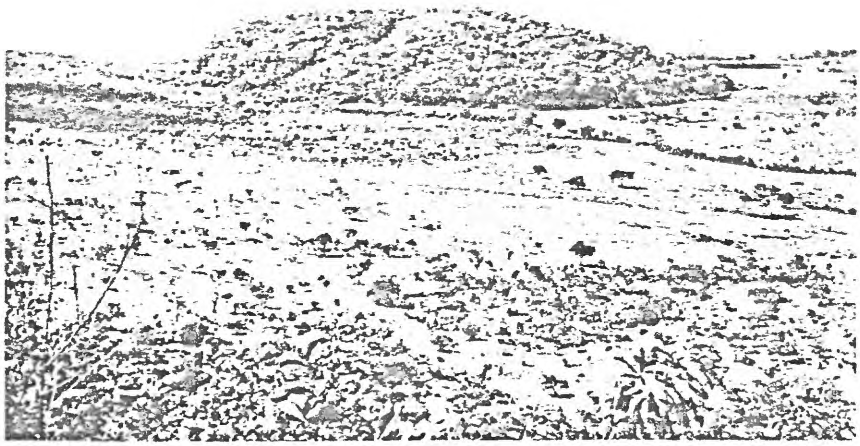


Figure 11.--Isolated hill underlain by massive- to thick-bedded limestone in upper part of unit B, about 6 km northeast of Vazante.

operation, approximately 10 m of thick-bedded limestone containing thin argillaceous partings grades laterally into shale and thin-bedded limestone in a distance of about 20 m.

Unit B is subdivided into six subunits, numbered B-1 at the base to B-6 at the top, primarily on the basis of photointerpretation of geologic and geomorphic features. The lateral limits of some of the subunits are shown as intertonguing with others (fig. 2). This is a reflection of the problem of rapid facies changes in the Paraopeba Formation. Subunit B-1 consists of marl and shale and forms a lowland occupied in part by the Rio Santa Catarina (fig. 12). Subunit B-2 is a narrow subdivision consisting of subdued parallel limestone ridges; the limestone appears to grade into the marl and shale of B-1 to the northeast. Subunit B-3 forms the prominent "mineralized cuesta" and is limestone along most of its length; shale and siltstone constitute a major portion of the subunit at the south end of Serra de Ouro Podre. Subunit B-4 is characterized by very low relief and probably is largely fine-grained clastic and argillaceous rocks and some interlayered thin-bedded limestone; a few isolated hills are underlain by thin- to medium-bedded limestone. Subunit B-5 is typified by numerous low cuestas and hills of moderately dipping thin-bedded to massive limestone; several hills are traceable on aerial photographs for 3 to 6 km. Subunit B-6 is distinguished by low, isolated hills of gently dipping to horizontal, thick-bedded to massive limestone beds that are discontinuous; the intervening areas are flat pasture land underlain by thin- to medium-bedded limestone, siltstone, shale, and marl.

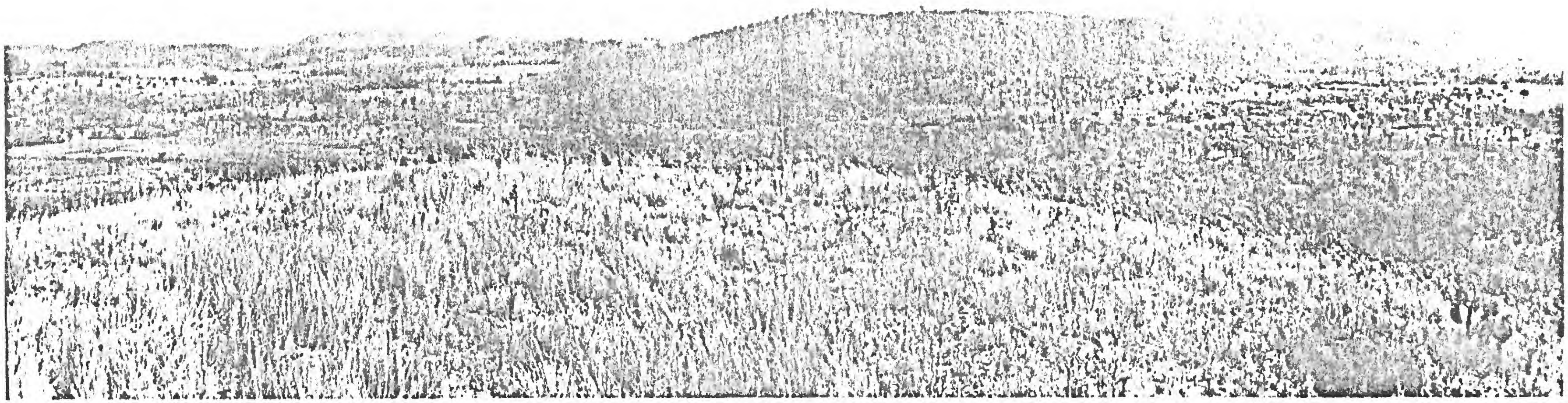


Figure 12.--Panoramic view of Serra do Poço Verde viewed from the south. The valley to the right (northeast) is underlain by shale and marl of subunit B-1. The ridge is Serra do Poço Verde, at the southwest end of the "mineralized cuesta"; the Companhia Mineira de Metais mine is on the opposite side of the ridge. Low hill in the foreground is unit A; hills in the background are unit C.

Subunits B-1, B-3, and B-4 were not separated in the northern part of the area because B-3 becomes subdued and unrecognizable. B-2 and B-3 terminate to the southwest against a tear fault. The rocks on the southwest side of the tear fault are mapped as unit B. Subunits B-5 and B-6 are not distinguishable immediately northeast of Vazante because of folding and possible stratigraphic complications. The basal contact of subunit B-5, however, appears to merge with the Mineira fault or become a bedding fault to the southwest beyond the tear fault.

Unit B has a minimum apparent thickness of about 300 m.

Unit C

Unit C underlies a terrain of undulating hills and cuestas in the western part of the area. It consists of interbedded siltstone, marl, sandstone, and dolomitic limestone, and local thin lenses of magnetite-bearing iron formation. These rocks are lithologically similar to those in unit B, but have a much higher ratio of siltstone and marl to limestone. Limestone underlies most of the prominent, sharp-crested cuestas while the sandstone generally underlies rounded, more subdued cuestas. The thickness of unit C probably exceeds 500 m; the top of the unit is not exposed in the map area.

STRUCTURE

The Vazante district displays many structures typical of a deformed belt. During the Brazilian orogeny (ca. 600-500 m.y. ago), older Precambrian rocks were thrust eastward over the western margin of the Bambuí basin along a front approximately 1,000 km long. Large-scale thrusting died out west of Vazante; the easternmost major thrust is in the Serra dos Pilões, about 30 km to the west of Vazante (fig. 1).

The effects of the orogeny are widespread at Vazante, and at least two phases of tectonism can be documented. First, low-angle, bedding, and step-bedding thrust faults developed, with some related folding. Low-grade metamorphism and penetrative deformation either preceded or was coeval with the thrusting. Second, broad cross folds deformed all previous structures. Interpretation of the types of structures is based both on their characteristics as seen in the field and as interpreted on aerial photographs, as well as on the geologic history of the surrounding region.

Folds

Four sets of folds (f_1 through f_4) are recognized. Set f_1 consists of folds that trend N. 20°-50° W., and range in size from microfolds less than 1 mm in size to some having wavelengths of 2-5 cm and amplitudes of 1-3 cm (figs. 5 and 8). These are best developed in unit B but are also present in units B and C where they were observed only in pelitic rocks interbedded with massive limestone and sandstone beds, and in close proximity to the contact between units B and C.

Set f_2 consists of two north-northwest-plunging anticlines, in unit A and in the lower part of unit B. The folds die out upward in the basal marl-shale member of unit B; the overlying cuesta-forming mineralized member is not affected by the f_2 folds. A west-plunging anticline, 2.5 km south of Lagoa Feia, is interpreted as belonging to set f_2. This fold is a complex anticline with possibly two stages of folding. A tightly folded axial zone is interpreted to be a f_2 fold that was refolded about a larger, more open f_4 fold. The f_2 folds have wavelengths and amplitudes of about 0.5 km and are at least 2 km in length. Set f_1 and f_2 folds are parallel.

The third fold set, f_3, consists of large-scale structures that trend N. 10° W. to N. 40° E. parallel to regional structural trends. All units and f_1 and f_2 folds are folded about f_3 axes. The folds are broad and open, and slightly asymmetrical; vergence is to the southeast, wavelengths are 0.5 to 2 km, and amplitudes are 0.1 to 1.5 km. Set f_3 folds are more abundant and more pronounced in units B and C than in unit A. Most of the folds are doubly plunging and discontinuous. Disharmonic folding is dominant with the more intense folding having occurred in resistant limestone and sandstone beds.

Set f_4 folds are large west-northwest-plunging folds that are transverse to the regional trend. All structures in the northern part of the area are folded about f_4 axes.

Set f_1 folds are the oldest and formed early in the Brazilian orogeny during the major period of widespread dynamic metamorphism. Lineations in all units (see below) are interpreted as being of this same age. Set f_2 folds postdate the Santa Catarina fault, which is folded about f_2 axes, but predate the Vazante fault and most structures in the lower part of unit B. Both f_1 and f_2 axes are more or less normal to the direction of Brazilian thrust faulting. Set f_3 folds are interpreted as being related to the major period of Brazilian folding and thrust faulting. Transverse folding of all structures by f_4 folds is the youngest event, postdating all thrust faulting.

Lineations

Three types of mutually parallel lineations were noted and include: 1) streaks of fine-grained sericite, 2) f_1 fold axes, and 3) traces of fractures that intersect parting and bedding planes. The streaking and smearing out of sericite appears to be the most widespread form of lineation. The fractures were noted only where f_1 folds were present and are parallel to f_1 axial planes. Quartz-filled fractures are common. The lineations occur throughout unit A and in most of the thin argillaceous beds in units B and C. In units B and C, lineation is most strongly developed at and near the contacts between argillaceous beds and sandstone and carbonate beds. The thinner the argillaceous bed between massive competent beds, the better developed the lineation.

Faults

Low-angle and bedding faults and related tear faults are believed to be the dominant style of faulting. The mineralized breccia zone on the "mineralized cuesta" may be related to this faulting. The upper and lower contacts of unit B are herein considered to be thrust faults throughout most of the map area. This faulting predates f_3 folding. High-angle normal faulting is probably relatively insignificant.

The Santa Catarina fault, which separates units A and B, marks a major contrast between the pronounced and pervasive penetrative deformation and low-grade metamorphism of unit A rocks and the generally locally developed penetrative deformation and much weaker low-grade metamorphism of unit B rocks. Beds on opposite sides of the fault are generally more or less concordant; however, minor but important discordances do occur. In the basal member of unit B, several marker horizons traceable on aerial photographs are truncated toward the north at a low angle against the fault where the fault bends northwest (fig. 2). The thickness of this basal member is also reduced by at least one half from the southern edge of the map to this point.

The unit B-unit C contact is thought to be a combination of low-angle thrust and bedding faults, herein named the Vazante fault. The contact is a folded surface as evinced by the general continuity of strata in both units. We did not observe the contact to be offset by high-angle faults as shown by Amaral (1968, fig. 2), but do agree with Amaral that it is a fault. We consider the contact to be one continuous fault that is a low-angle thrust southwest of the north-plunging anticline about which it is folded and that it climbs upsection to the northeast or east, becoming a bedding fault east and northeast of the anticline. Structures in unit B, south of the anticline, consist of a series of broad open folds, apparently involving the same beds, indicating that the dip of unit B is very low in this area. Unit C, in this same area, dips uniformly, more steeply, and is not folded, thus indicating a structurally discordant relationship across the contact. Strata along the fault in this interval are discordant and irregular, probably indicating drag folding and related faulting. East and northeast of the anticline beds in both units are more or less parallel to each other.

Minor offsets or suspected offsets of strata in unit B have been explained by previous workers as the result of high-angle normal faults. However, on aerial photographs numerous marker horizons can be seen to be continuous both above and below some of these offsets. Thus the faulting that is responsible must be confined by these marker beds. We suspect that multiple bedding faults and step-bedding faults developed, and associated with this, differential movement of the intervening beds formed tear faults that terminated at the bounding bedding faults (fig. 13). In this fashion an uptilted sequence of rocks would have tear faults that offset only a few beds in a limited stratigraphic interval and would have all the characteristics of high-angle normal faults, but would terminate abruptly at overlying and underlying layers.

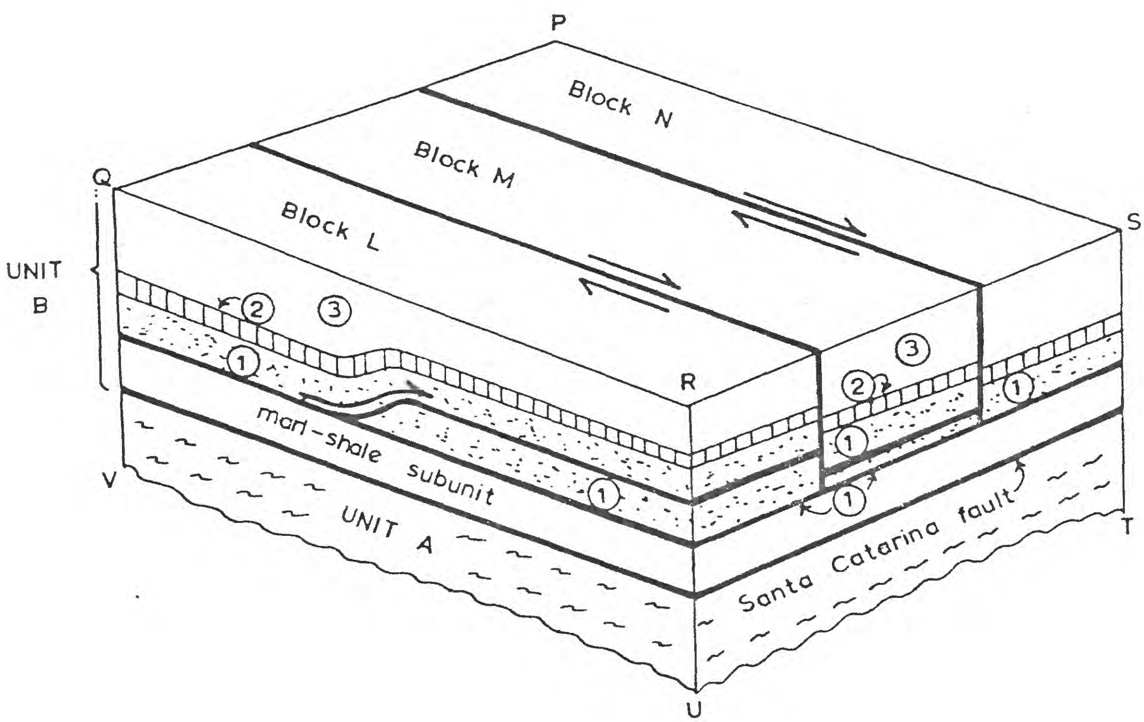


Figure 13.--Block diagram showing hypothetical tear faults bounded by step-bedding-plane and thrust faults. Beds 1, 2, and 3 are broken by tear faults into blocks L, M, and N subsequent to the formation of the step-bedding-plane fault. On face RSTU three possible relationships are shown, based on differential movement between the three blocks. The face of block L is self-explanatory. The faces of blocks M and N are cross sections immediately in front of a step fault and before step faulting is accomplished, respectively. An unbroken block would overlie blocks L, M, and N on a bedding fault that is surface QPSR.

Two examples of this type of tear fault relationship will illustrate the point. About 2 km southeast of Vazante along the road to Patos de Minas, there is, on the north side of the road, a low ridge underlain by at least 20 m of northwest-dipping limestone. This limestone is not present in the drainage ditch alongside the road, a distance of about 10 m from limestone outcrops. Instead, only folded shale is present in the ditch and the road bed. A second case in point is in the stream that crosses the "mineralized cuesta" about 0.75 km west of the air strip at Fazenda do Ingá. The cuesta northeast of the stream cut is underlain by 50-80 m of massive to thick-bedded limestone whereas in the stream cut and to the southwest along the cuesta moderately folded siltstone and shale are present. The change from limestone to siltstone can be narrowed down to an interval of about 10 m. In both areas bounding strata are not offset. Thus tear faulting bounded by bedding thrust faults is interpreted to explain the relationships. Facies changes may have been the dominant factor in controlling the location of such tear faults.

The "mineralized cuesta" has been interpreted as a northwest-tilted fault block by previous workers (Branco, 1962; Carvalho and others, 1962; Amaral, 1968). The cuesta-forming strata are folded about f_4 fold axes, which means that if there is a frontal normal fault, it predates f_4 folding. This type of alternating compressive and tensional tectonics is atypical of deformed belts. An alternative explanation, one favored in this report, is that of differential weathering of a poly-folded and thrust-faulted sequence of interbedded resistant and less resistant strata, resulting in the development of curved, irregular cuestas and intervening valleys.

The mineralized breccia zone, on the dip slope of the "mineralized cuesta," has also been considered by previous workers (Moore, 1956; Branco, 1962; Carvalho and others; Guimaraes, 1962; Amaral, 1968) as being due to normal faulting. Bounding faults of the zone, which ranges from less than 1 m to 200 m in width, are steep, dipping both to the northwest and southeast. The zone is also folded about f_4 fold axes. There are several possible explanations for the formation of the breccia zone. The one favored here is that the breccia developed along the step of a step-bedding fault, herein named the Mineira fault, that originated during the major period of Brazilian tectonism, probably prior to or coeval with f_1, f_2, and (or) f_3 folding, but definitely before f_4 folding. Several other interpretations include: a high-angle fault that has been folded, as proposed by previous workers; a fault-zone vein, pre-f_4 folding but post-thrusting, perhaps a rebound tensional structure; a faulted and metamorphosed Mississippi-valley type or similar type of "stratabound" deposit; a faulted and metamorphosed massive sulphide type of syngenetic deposit.

RESERVES

The zinc deposits occur in breccia zones along the Mineira fault, primarily along the dip slope of the "mineralized cuesta." These breccia zones are variable in width and depth, ranging from 1 to 200 m in width and as much as 80 m deep (fig. 14). A wide variety of minerals are present and are listed in decreasing order of abundance: hemimorphite (referred to as calamine in Brazilian reports of the district), willemite, hydrozincite, cerussite, smithsonite, chalcocite, brochantite, pyromorphite, covellite, zincite, cuprite, native copper, malachite, linarite, aurichalcite, acanthite, and native silver (Amaral, 1968). The main ore minerals are hemimorphite, willemite, and

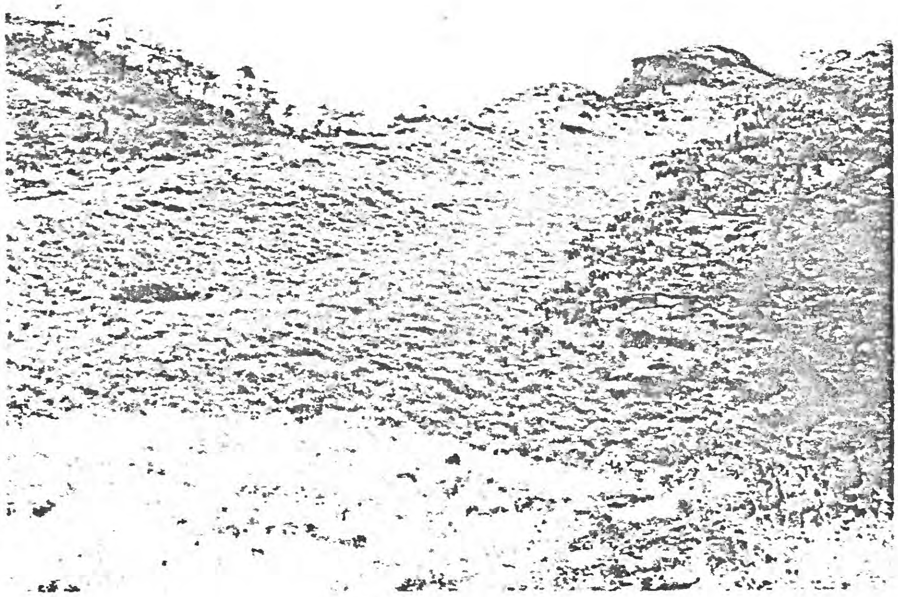


Figure 14.--Resistant ridge of mineralized breccia zone (primarily hemimorphite, hydrozincite, willemite) on the north end of Serra do Poço Verde. Note the complete absence of trees in the zone of mineralization.

hydrozincite. Secondary zinc silicate minerals extend downward to at least 80 m. Primary sulphide minerals are recognized at greater depth, but their limits are poorly defined and they apparently occur in irregular small bodies.

Proven reserves on the Companhia Mineira de Metais concession are about 6,200,000 tons of 16 percent zinc ore (largely hemimorphite ore) and an additional 800,000 tons of 40 percent zinc ore (large willemite ore), or about 1,312,000 tons of zinc metal (White and Nagell, 1975). Reserve data are not available for the Ingá deposit but probably are of a similar size. Probable and possible reserves half again as large as proven reserves seem to indicate that total zinc metal reserves could be as much as 3 million tons.

CONCLUSIONS

The Vazante district, being located along the leading edge of a deformed belt, has been subjected to considerable compression, and the rocks have responded accordingly. Low-grade dynamic metamorphism of argillaceous rocks, broad folding, and low-angle and bedding faulting with associated tear faulting dominate the structural history. Essentially all the structures in the Vazante district were probably formed during the Brazilian orogeny (ca. 600-500 m.y. ago); subsequent structures are minor in areal distribution, though possibly very important with regard to mineralization.

The breccia zone along the "mineralized cuesta" is only a very small part of the area, but economically is the most important. The breccia is believed to have developed in response to step-bedding-plane faulting along the base of the carbonates underlying the "mineralized cuesta" (fig. 13). This resulted in brecciation of carbonate and argillaceous rocks. The amount of stratigraphic separation is unknown, but probably was not large.

The origin of the mineralizing fluids at Vazante is very poorly understood. However as a corollary to the different structural interpretation for the district, the zinc is interpreted as being syngenetic in carbonate rocks of the Bambuí Group. The structures formed during the Brazilian orogeny, primarily breccia zones along faults, provided the plumbing system for later migration of ore-bearing fluids. Redeposition in the breccia zone along the "mineralized cuesta" formed a deposit that subsequently was oxidized by surface or near-surface waters. During the redeposition and oxidation phases, possibly during late Mesozoic or early Cenozoic time, the character of the breccia was so altered that it is now impossible to determine whether the breccia is tectonic or solution in origin. Solution and collapse features are common in the breccia zone, but probably only reflect the latest history of the zone.

This interpretation would suggest that future exploration for Vazante-type deposits should be concentrated along the deformed belt where folded carbonate rocks are interbedded with argillaceous rocks. It is in this type of stratigraphic situation that disharmonic folding is most likely to lead to bedding and step-bedding faulting, and thus lead to the development of breccia zones that might act as depositional sites for ore-bearing fluids.

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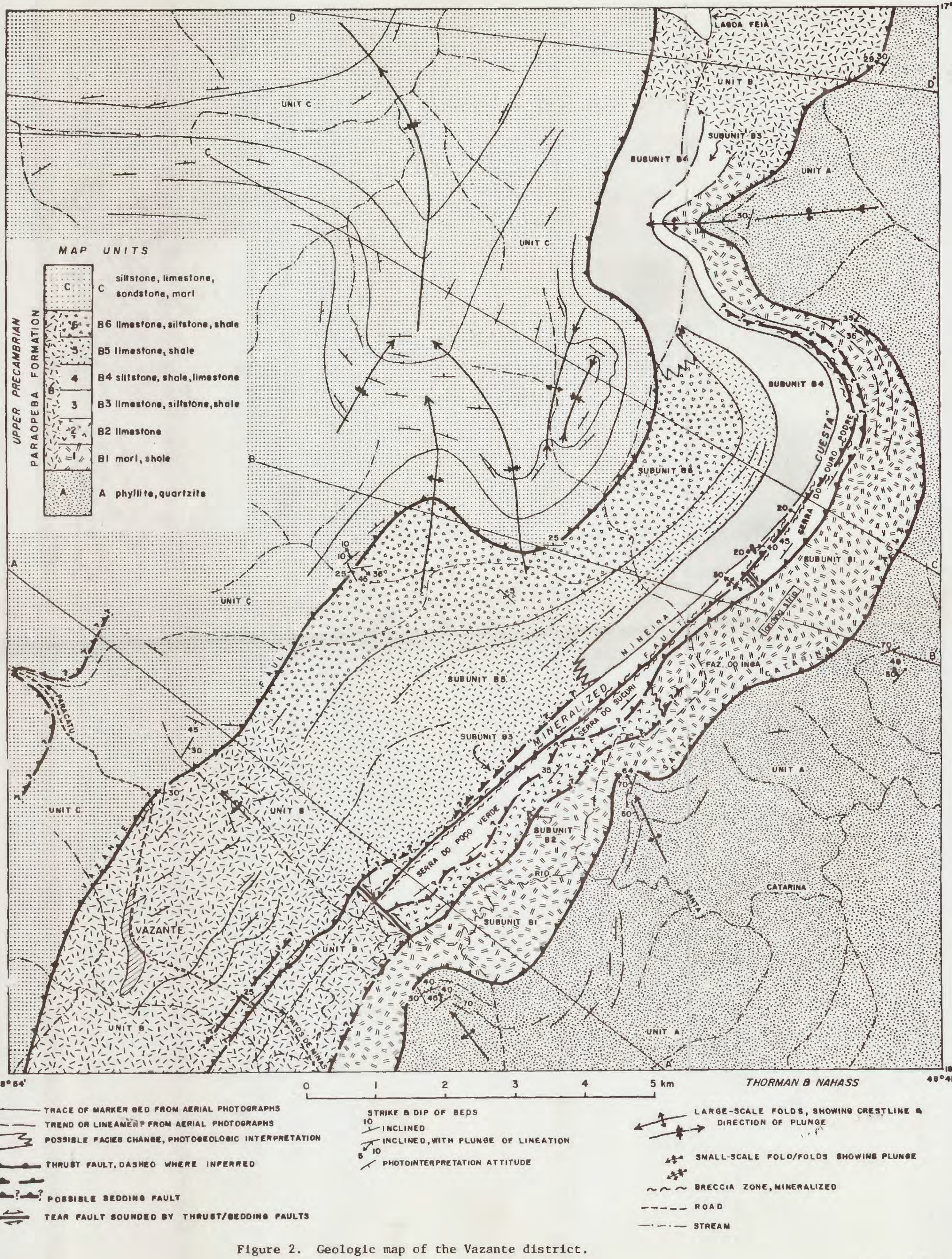

Figure 2. Geologic map of the Vazante district.

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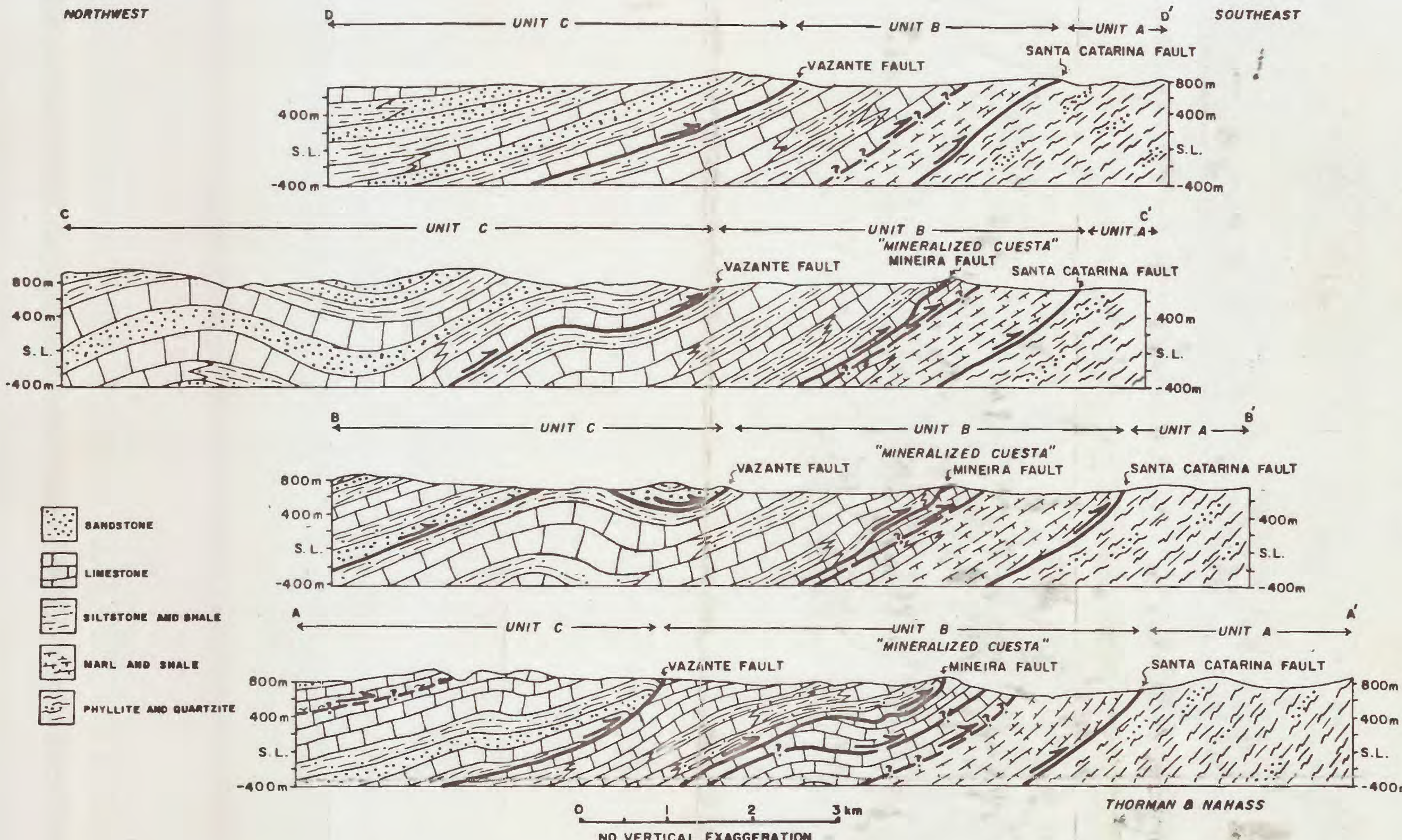

Figure 3. Geologic cross sections of the Vazante district.

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