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PETROGRAPHY AND GEOCHEMISTRY OF MAFIC ROCKS OF THE PERALVILLO FORMATION IN THE SABANA POTRERO AREA, CENTRAL DOMINICAN REPUBLIC

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ABSTRACT

Mafic volcanic rocks composed of pillowed and massive units together with minor hyaloclastites, with a thickness of between about 1200-2300 m form a narrow belt immediately north of the Loma Caribe serpentinized peridotite within the Median Belt, in the central Dominican Republic. At Sabana Potrero a zone of altered rock with disseminated sulfide and stockwork, structurally overlies massive sulfide ore bodies within the mafic volcanic rocks. The structural and stratigraphic information indicates that these mafic and volcanic rocks form the base of the Peralvillo formation of apparent Late Cretaceous age and are probably equivalent to the vitric and crystalline basalts of the Siete Cabezas Formation to the south of the peridotite belt.

The texture of the volcanic rocks ranges from fine-grained microporphyritic to poorly-developed sub-ophitic to granular textures in the coarse-grained varieties. Clinopyroxene and plagioclase make up 90% of the rocks. The dominant alteration minerals are chlorite, prehnite, and epidote. Iron titanium oxide minerals are ubiquitously replaced by leucoxene. Mafic lavas and intrusives (diabases) have been analyzed for major and trace elements mainly from the drill cores of the Sabana Potrero area, but also from surface exposures. Most of the rocks are olivine-hypersthene normative and some contain normative quartz. TiO_2 ranges from 0.43 to 2.8% and varies with the Fe/Mg ratio allowing correlations of different flow units between drill holes. Variation diagrams show that both the lavas and intrusive phases belong to a comagmatic sequence.

Chondrite-normalized Rare Earth plots show enrichment in Ce over La, depletion in Nd and a positive Eu anomaly. Trace element spider diagrams, normalized to N Type MORB, show consistent patterns for all samples. Characteristic features are relative enrichment of Ce over La, 2 to 7 times enrichment in Nb and Ta, and slight depletion in Nd. Relative concentrations of Ti, Zr, Hf, Y are constant and similar to those of present-day ocean floor (MORB) basalts. Sabana Potrero basalts are chemically distinct from Duarte metabasalts.

INTRODUCTION

Peralvillo (mispelled as Peravillo) Formation was the name given by Bowin (1966) to a narrow belt of essentially unmetamorphosed rocks that lie between the Loma Caribe peridotite and the schistose rocks of the Maimon Formation within the Median Belt of the Cordillera Central (Fig. 1).

Bowin (1966) recognized three volcanic rocks types within the Peralvillo Formation, namely fine and course tuff, lapilli-tuff and microporphyritic aphanitic volcanic rocks. The most common volcanic flow rocks were described as pyroxene andesite with microphenocrysts of plagioclase and clinopyroxene. An outcrop of calcareous black pelite with abundant carbonaceous material from south of Yamasa was also described.

Boisseau (1987) reported on several measured sections in the Peralvillo Formation. He described the sequence exposed in the Arroyo Toro as consisting of layered gabbro at the base and overlain by basalts intruded by diabase. These basic rocks are in contact with the Loma Caribe peridotite to the south. This is similar to the section measured by Jimenez from the Arroyo Los Martinez (Jimenez and Lewis, 1989), except that Jimenez did not find gabbro at the base of the section in contact with peridotite. Even though the exact nature of the gabbroic rocks and the nature of the contact with the peridotite to the south is not clearly established the association of basic rocks with the peridotite is suggestive of an ophiolitic sequence as pointed out by Boisseau (1987). The upper part of the sequence above the basalts in the Arroyo Toro and Arroyo Los Martinez consists of volcaniclastic and epiclastic sedimentary rocks including varicoloured cherts. Unfortunately, radiolaria from these cherts did

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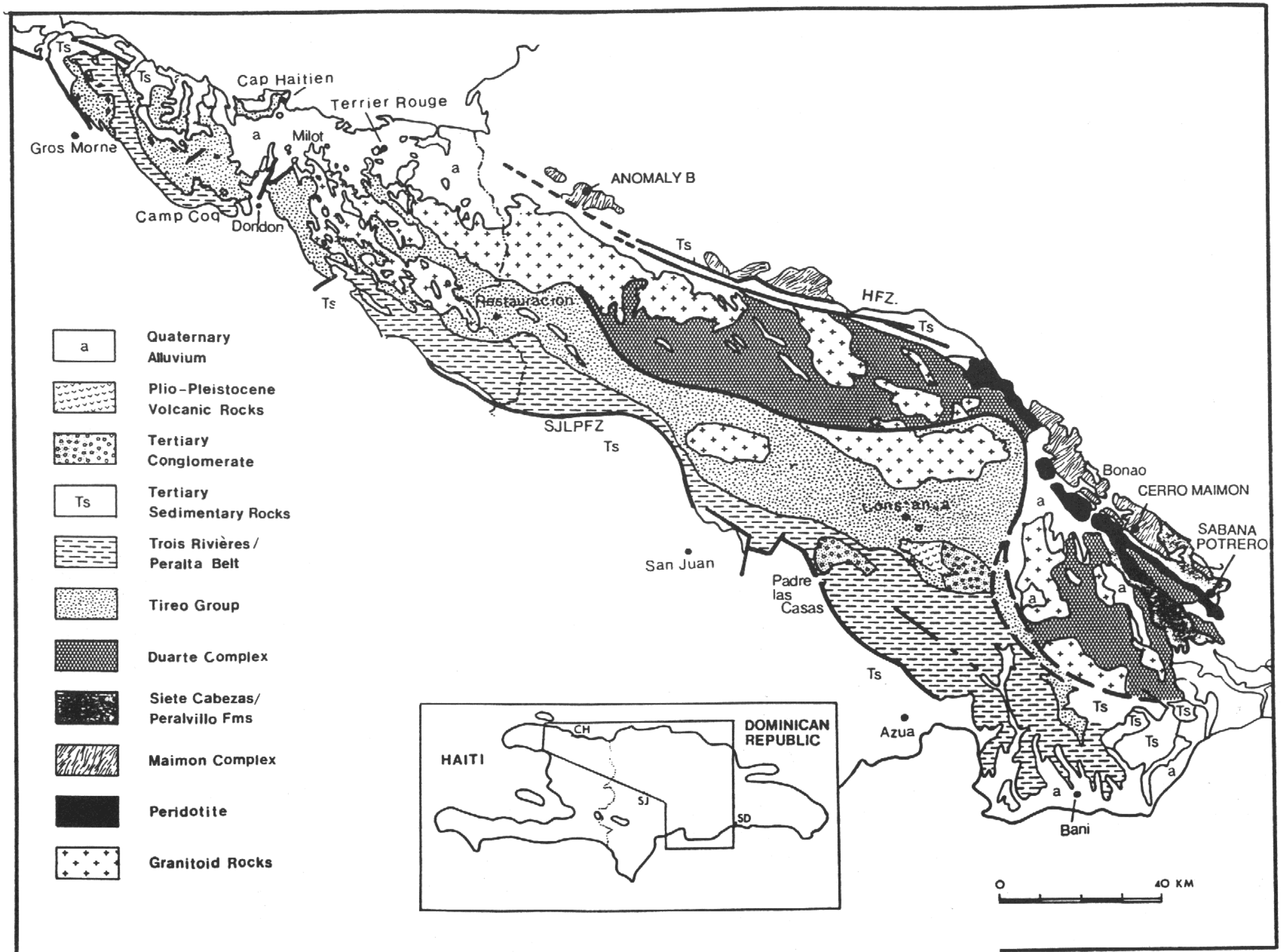

Fig. 1 Generalized geological map of the Median Belt of the Dominican Republic showing the Peralvillo Formation north of the peridotite belt and the location of the Sabana Potrero, Cerro Maimon and Anomaly B prospect areas (Brouwer and others, 1989).

not give an age more precise than Cretaceous (determinations by P. de Wever, in Boisseau, 1987). However, Boisseau (1987) tentatively correlated these cherty beds in the Peralvillo with similar sedimentary rocks in the upper part of the Siete Cabezas Formation which gave a Cenomanian-Turonian age (Boisseau, 1987).

In the quest for massive sulfide mineral deposits geologists from Falconbridge Dominicana have had the opportunity to examine the rock types within the Peralvillo belt in two areas, namely at Cerro Maimon, east of the town of Maimon, and at Sabana Potrero. A summary of the recent work on the geology at Cerro Maimon was presented at the 12th Caribbean conference by Jimenez and Lewis (1989). The work in both these areas has shown the geology is far more complicated than in the preliminary description given by Bowin (1966).

GEOLOGY

This is an initial report concerned within the small area under prospection by Falconbridge Dominicana at Sabana Potrero located 4.5 km southwest of the town of Yamasa (Fig. 1), and 25 km east of Cerro Maimon and the Arroyo Los Martinez. A preliminary map of the geology over an area of just less than one square kilometer at Sabana Potrero is given in Figure 2. The dominant rocks in the area are aphanatic pillow basalts intruded by diabase, but details of the alteration and contacts between pillows and intrusive phases are best studied in drill cores. The mafic rocks lie to the north of, and for the most part are in fault contact with an arm of the Loma Caribe serpentinized peridotite. Small bodies of metamorphosed diabase and gabbroic rock, some with banding, are included in the serpentinized peridotite.

A narrow east-west belt, about 100-150 meters wide at the surface, and more than 100 m thick, of altered (bleached) rock with disseminated sulfide and stockwork (quartz-sulfide veins), structurally overlies restricted massive sulfide ore bodies (Figs. 2 and 3). Boulders of highly oxidised mafic rocks (gossan) occur at the surface above the massive sulfide deposits. The mineralization in the stockwork is irregular and patchy and is mainly in the form of anastomizing veins and veinlets of silica (both quartz and jasper) and sulfide (mainly pyrite with minor chalcopyrite). Chlorite is pervasive through the stockwork zone and occurs within the veins, often as large clots. Epidote is rare in the stockwork zone. The massive sulfide is composed of mainly pyrite with chalcopyrite and minor sphalerite.

The massive sulfide ore bodies are distributed at depth along a north-west trend (parallel to the regional trend) and dip to the south. The trend and position of the massive sulfide deposits have been interrupted and restricted by the mafic intrusive bodies. The southerly dip and the form of the stockwork above the massive sulfide suggests the sequence is overturned.

The mafic volcanic rocks are composed of pillowed and massive flow units (eg drill hole SP-19). The pillowed units can be subdivided on the basis of their selvage characteristics into those consisting of thick well-developed selvages with massive epidote, jasper and chert and those containing irregular cavities with epidote-quartz-chlorite. Laminated cherts within the flow units in hole SP-17 indicate a sedimentary origin for at least some of the chert. In places the pillows are brecciated and in thin section appear granulated and sheared. Fracture fillings composed of quartz, epidote and carbonate are common.

The flow units are fine to medium-grained rocks . Chilled flow contacts can be observed within the flow units with epidote alteration prominent along contacts. Flow textures are most prominent in the fine-grained rocks beneath the massive sulfide, although textures in the mafic volcanic rocks above the massive sulfide have been obscured by the more extensive alteration in these rocks.

In the footwall to the massive sulfides the mafic volcanic rocks are cut by coarse-grained massive mafic rocks. The intrusive phases are recognised by their coarse grain size, relative freedom from alteration and mineralization, and cross-cutting contacts. These rocks show the same basic mineralogical features as the flow units. In the hanging wall, the alteration is similar in both fine and coarse-grained rocks so that it is difficult to distinguish the intrusive phases.

The medium- and course-grained rocks are composed of mainly clinopyroxene and plagioclase and show a sub-ophitic texture. Skeletal ilmenite/titanomagnetite, almost entirely altered to leucoxene is prominent in some rocks. Chlorite alteration is pervasive and chlorite makes up to 25 per cent of some rocks. Plagioclase is commonly albitised. Finer-grained rocks are microporphyritic with laths of plagioclase and pyroxene in a fine-grained

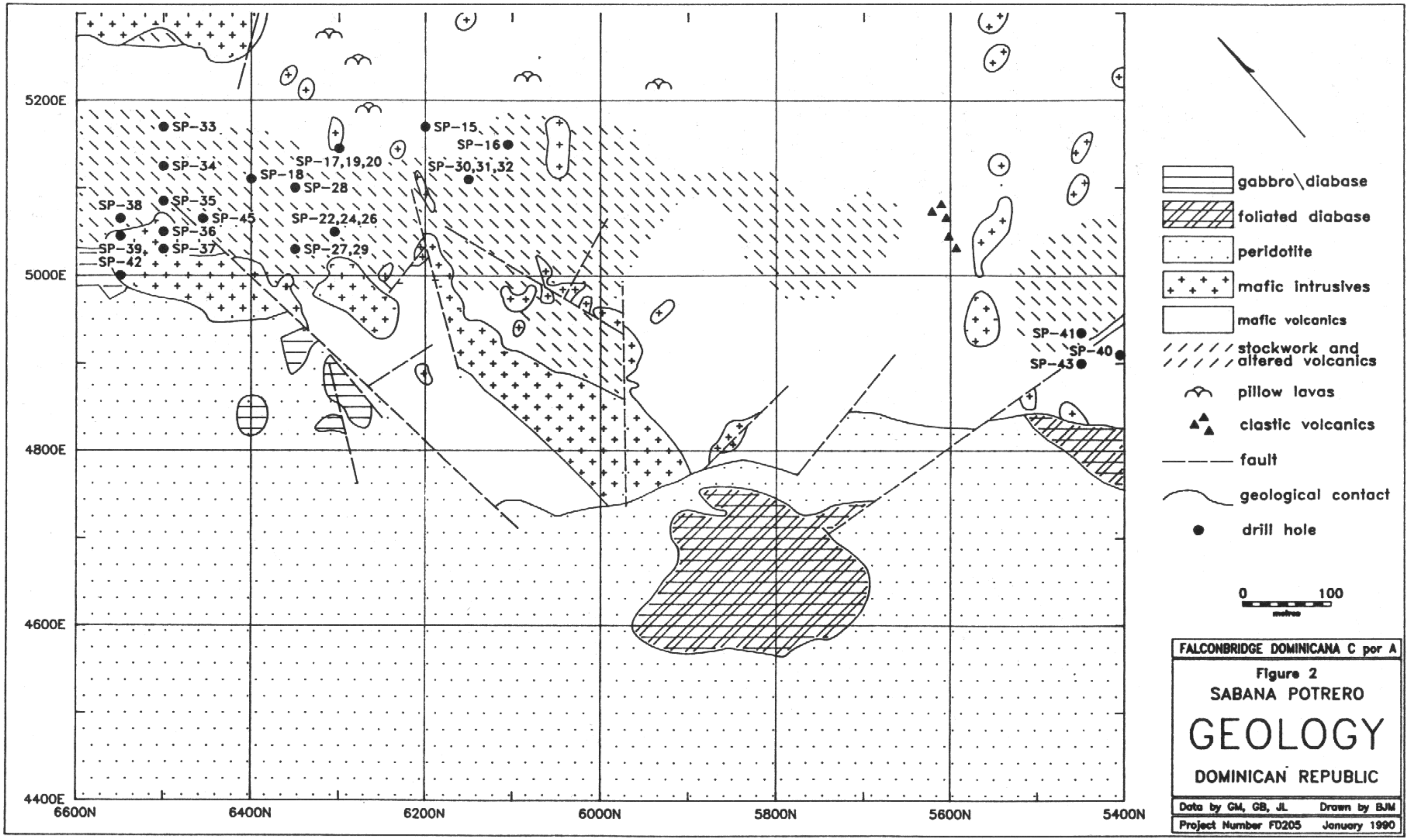

Fig. 2 Geological map of the Sabana Potrero area. Numbers (SP-15 etc.) give location of drill holes.

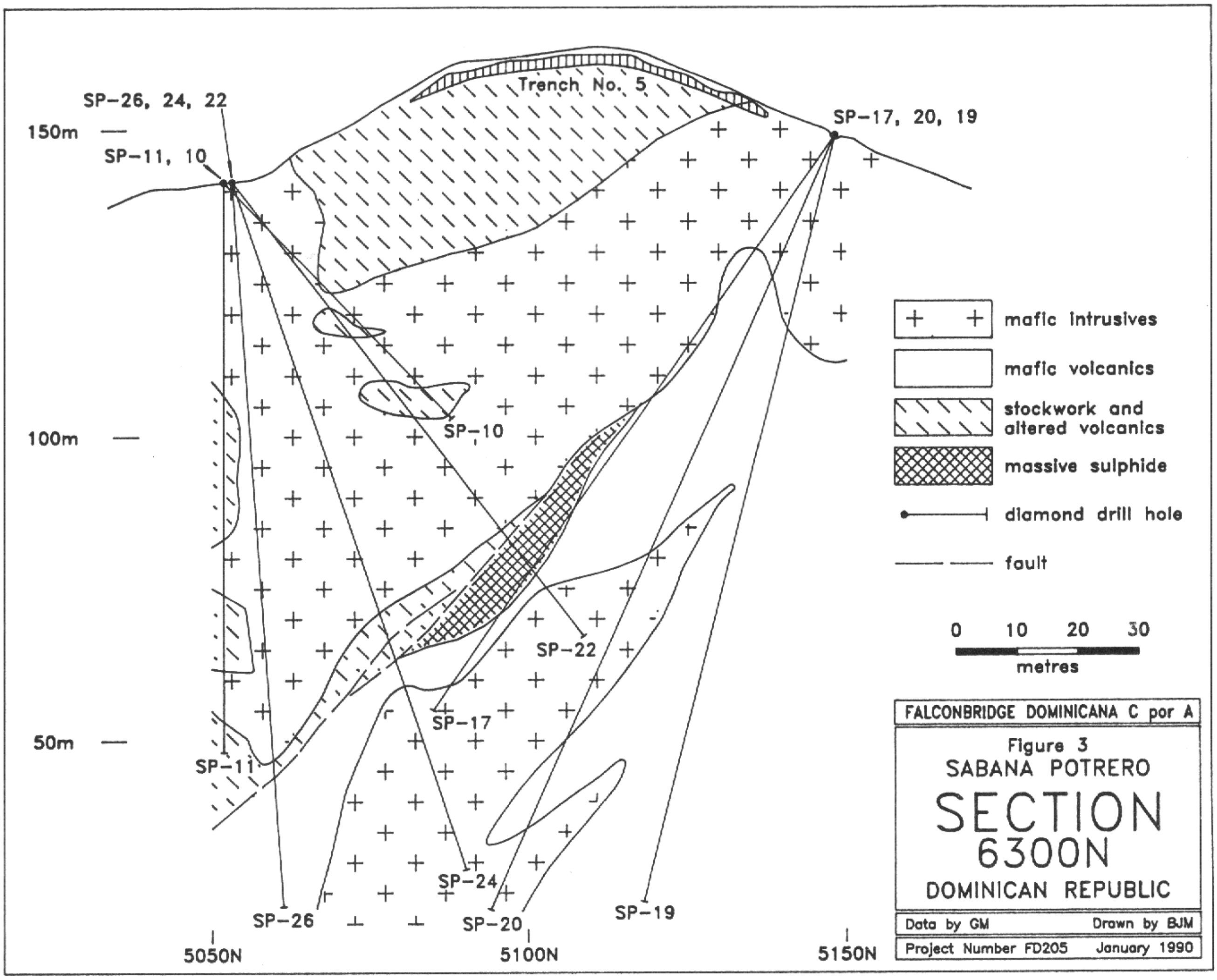

Fig. 3 North-south cross section through drill holes SP-17,19,20 and SP-22,24,26 showing relations between basalt flows, mafic intrusive phases, stockwork and massive sulfide ore.

matrix. Thus the rocks have a low grade greenschist assemblage and can be loosely referred to as spilites.

This pervasive alteration and the extensive veining in the Sabana Potrero basalts is common in mafic rocks erupted on the sea flow described from other areas. However, at this time the nature of the alteration at Sabana Potrero and degree of mobility of the elements has been examined in only a general way.

GEOCHEMISTRY

At the time of writing thirteen drill holes have been sampled for chemical analysis. Forty-two whole rock analyses of all textural types have been made for both major and trace elements.

Of these, 30 samples have been analyzed for trace elements including Rare Earth elements (REE). Major elements were determined by X-ray Fluorescence on fused powders. Representative analyses are given in Table 1. The Loss on Ignition (LOI) value, which varies between 2 to 3 percent in most of the rocks is due to water present in alteration minerals, mainly chlorite. The overall similarity in the analyses is immediately apparent but there is some significant variation. The rocks are hypersthene-olivine normative tholeiites. Only two of the analyses (from core SP-36) are quartz normative, showing that the rocks are basalts even though some samples show up to 54% SiO_2 when calculated on a water-free basis.

TiO_2 varies from 0.43% to 2.31% and is highest in the main flow rocks analysed from cores SP-16, SP-17 and SP-22. The MgO content ranges from 4.63% to 9.31% and varies inversely with TiO_2. The highest MgO content is in sample SP-28/70.2 and this lava has the lowest TiO_2 content (Table 1). Na_2O is relatively high in comparison with most present day fresh young basalts suggesting that this element might have been concentrated by sea water alteration.

Variations in major element chemistry and the chemical relations between the flows and intrusive phases can be examined using a TiO_2:FeO/MgO diagram (Fig. 4). Samples showing the lowest TiO_2 and lowest FeO/MgO ratio are those from the middle flows from drill cores SP-27 and SP-28. Samples from flows lower down in these cores contain almost twice as much TiO_2 with only slightly higher FeO/MgO ratios and presumably represent a different magma batch.

In contrast, definite flow rocks from drill holes SP-17, 19 and 20 show the highest TiO_2 contents and highest FeO/MgO and must represent the most differentiated lavas. Unique parallel trends can be distinguished for the flow rocks from drill holes SP-17 and SP-19 (although some points lie off the trends). These linear trends are surprising since the rocks are altered to low grade greenschist assemblages which would suggest that Fe and Mg would probably have been mobilised. Samples SP-26/28.65 and SP-24/113.5 are gabbroic rocks and represent an intrusive phase into the lavas. These rocks have a lower TiO_2 content and lower FeO/MgO ratio than most of the lavas analyzed from SP-17, 19 and 20. On the other hand sample SP-26/105.6 (lower in the drill hole) is a definite volcanic rock and is assumed to lie below the sulfide zone (Fig. 3). The chemistry of this rock is very similar to the intrusive sample above and different from most of the more fractionated lavas from higher in drill holes SP-17 and 19 and discussed earlier. Sample SP-19/19.38 from the top of hole SP-19 is correlated with the intrusive rock in holes SP-24 and SP-26 (Fig. 3).

The three samples analysed from drill hole SP-30 are from both the volcanic and diabase facies of the drill core. All three analyses are similar in composition and plot in a field along with other analyses approximating 1.3 to 1.6% TiO_2 and an FeO/MgO ratio ranging from 1.6 to 1.9. In fact, one half of the Sabana Potrero samples so far analysed fall in this compositional range. This could therefore be the main parental magma composition from which the magmas such as represented in the cores from drill holes SP-17, 19 and 20 with higher FeO/MgO fractionated.

Analyses for 25 trace elements were made on 30 samples using multi-element techniques. Most trace elements, including the Rare Earth Elements (REE), were determined by Instrumental Neutron Activation Analysis at the McMaster University Reactor Facility by Neutron Activation Services (NAS). Rb, Sr, Ba, Cr, Zr, Nb and Y were determined by X-ray Fluorescence. In order to demonstrate the characteristic features and comparisons the trace element data of representative samples have been normalized to N-Type MORB and plotted in a multi-element (spider) diagram (Fig. 5). Because the rocks have undergone low grade metamorphism, which probably included sea water alteration, the least mobile elements such as Nb, Ta, Zr, Hf, Ti, Y, Th and the REE's should be used as discriminants.

Important features are:

1) Sabana Potrero basaltic rocks display relatively high Nb-Ta concentrations. Nb in all samples ranges from two times to almost seven times N-Type MORB.

2) La/Ce ratios (N-Type MORB normalized) are negative, in contrast to Duarte metabasalts, in which they are positive.

3) In a few samples HFS elements show concentrations slightly above those of N-Type MORB but in most samples the concentrations are almost equal to, or are lower, than N-Type MORB. Sample 28/70.2 is distinctly depleted in P, Ti, Y and Tb with respect to N-Type MORB.

4) On the Rare Earth Element (REE) plot, normalized to chondrite (Fig.6), the samples show flat to jagged (sea-saw) patterns and concentrations of between about five times and twenty-five times chondrite. Most samples show relatively high concentrations of Ce and Eu, and depletion in Nd. Three samples from drill holes SP-27 and SP-28 show depletion in the light REE.

5) The variation in REE's in the Sabana Potrero basalts differs from the typical patterns of metabasalts from the lower unit of the Duarte Complex which shows smooth rotated patterns with high concentrations of light REE's (Draper and Lewis, 1989; 1990 submitted).

6) In terms of their Ti-Y-Zr ratios (Fig. 7) (using the discriminant diagram of Pearce and Cann, 1973) most of the Sabana Potrero basalts fall in the Ocean Floor basalt field (OFB).

One chemical analysis is presented (Table 1) of an altered volcanic rock (SP-26/22.16) from the stockwork zone. In comparison with the analyses of the main zone of mafic volcanic rocks (Table 1) this rock has lost most of its Ca, Na, K, and some Al and Mn. The rock has gained some Si, Fe, possibly Mg and H_2O and other volatiles. Except for an apparent loss of some Ni the trace elements seem to be relatively immobile. Note the difference in the chemistry of this type of alteration associated with the stockwork as opposed to the alteration associated apparently with sea water, producing greenschist-type mineral assemblages through the major zone of mafic volcanic rocks.

SUMMARY AND CONCLUSIONS

The data presented here are the initial results of a detailed study over a limited area of a sequence of submarine tholeiitic basalts of apparent Late Cretaceous age within the Peralvillo Formation.

The basaltic pile at Sabana Potrero which approximates 1200-2300 m in thickness, consists of pillow basalts, fine-grained volcanic rocks without pillows, and coarser-grained rocks (diabases) which are intrusive into the volcanic pile. The chemical data show that the basaltic rocks are a consanguinous suite presumably erupted over a short time interval. Most of the rocks show a consistent composition but certain of the lavas from drill holes SP-15,16,17,19 and 20 represent more fractionated liquids. Certain rocks from cores SP-27 and 28 are distinctly depleted in Ti, P, Y, and Tb compared with the other Sabana Potrero basalts and probably represent a separate magma batch. In terms of their trace element chemistry the Sabana Potrero basaltic rocks show many of the features of MORB basalts but exhibit anomalously high Nb-Ta contents with respect to N-Type MORB.

The field association of massive sulfide ore bodies within pillowed and massive flows juxtaposed against serpentinized peridotite points toward a Cyprus type of ophiolitic association. The structure suggests the sequence is overturned. The structural,textural and compositional relations clearly indicate that the massive sulfide bodies are synvolcanic in origin. Although massive gabbro bodies are present in the association, layered gabbroic cumulates, sheeted dikes and more felsic differentiates which should be present in the ophiolitic sequence have not been located at Sabana Potrero. However, Boisseau (1987) has reported layered gabbros at the base of the basaltic rock sequence at Arroyo Toro, near Cerro Maimon, 25 kms to the north-west of Sabana Potrero.

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Table 1
Chemical analyses of basaltic rocks from Sabana Potrero.

	Variation	SP-17/26.73m	SP-28/70.20m	SP26/28.65m	SP36/22.16m
SiO_2	47.6-53.9	49.4	51.5	51.3	55.88
TiO_2	0.43-2.31	2.31	0.43	1.49	0.93
Al_2O_3	12.6-15.5	12.8	13.9	14.7	11.8
FE_2O_3	7.8-14.6	14.6	7.8	11.4	15.3
MnO	0.16-0.24	0.24	0.16	0.21	0.11
MgO	4.63-9.31	5.93	9.31	5.96	9.02
CaO	5.9-11.5(16.2)	7.94	9.24	8.87	0.56
Na_2O	2.59-4.83	3.5	3.67	3.61	0.09
K_2O	0.08-0.89	0.13	0.33	0.39	0.03
P_2O_5	0.04-0.39	0.2	0.04	0.15	0.08
L.O.I.	1.7-3.4	2.7	2.8	2.4	5.8
	Total	99.8	99.2	100.5	100
Cr	38-480	87	480	130	63
Ni	21-120	44	110	47	28
Y	12-40	36	12	35	16
Nb	5-18	7	13	7	6
Zr	18-143	143	18	73	75
La	0.6-4.6	4.5	0.9	2.8	0.6
Ce	4-22	20	4	15	5

Notes: SP-17/26.73 and SP-28/70.20 are basalt flows, Sabana Potrero
SP-26/28.65 is a coarse grained rock (diabase) apparently intrusive into the flow rocks, stockwork and massive sulfides.
SP-36/22.16 is a sample of altered basalt--part of the stockwork.

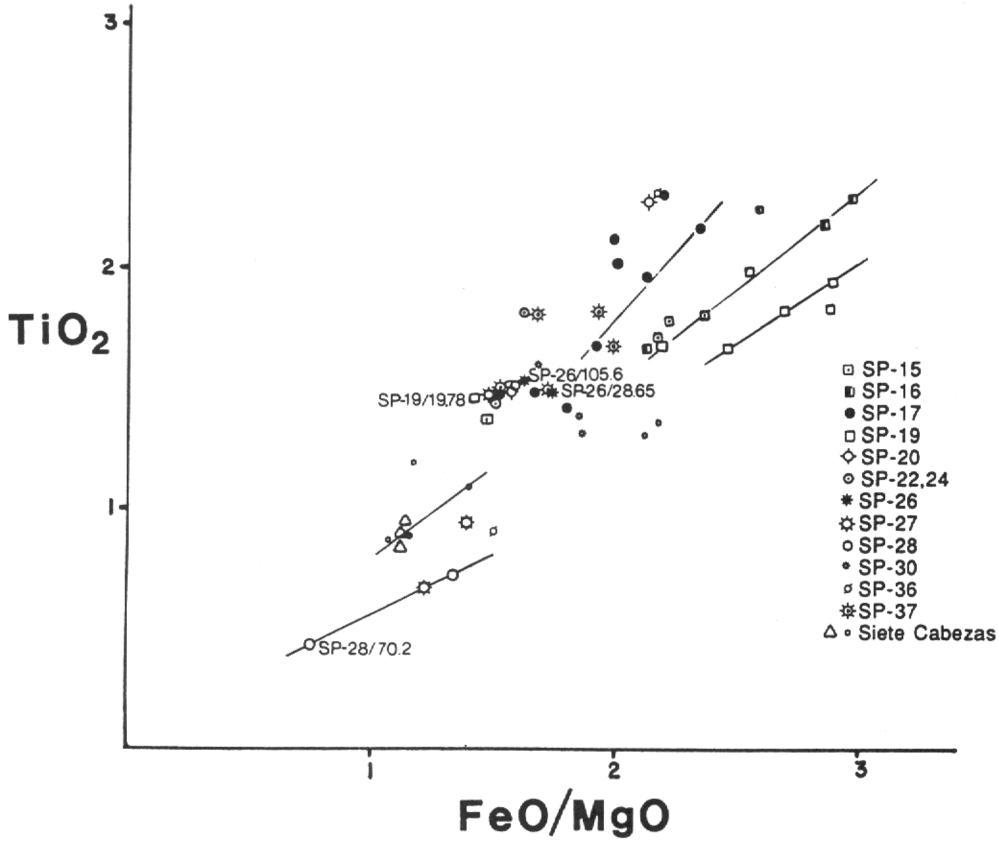

Fig. 4 Plot of TiO_2: FeO/MgO for the basaltic rocks from the Sabana Potrero area.

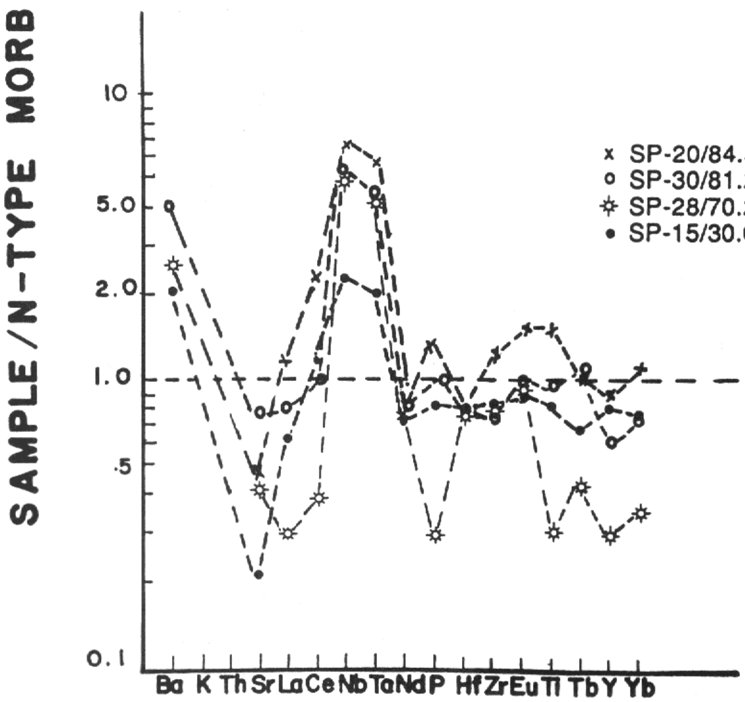

Fig. 5 Multi-element plot, normalised to N-Type MORB, showing element variation for representative basaltic rocks from the Sabana Potrero area.

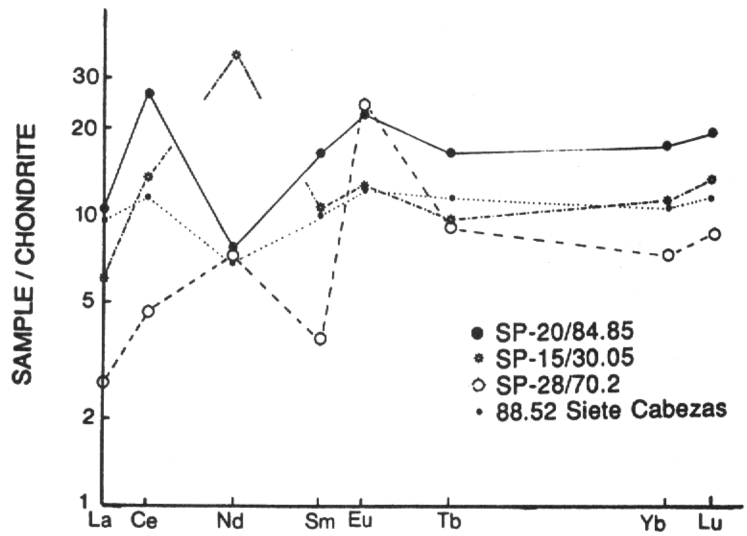

Fig.6 REE plot, normalised to chondrite, for representative basaltic rocks from the Sabana Potrero area.

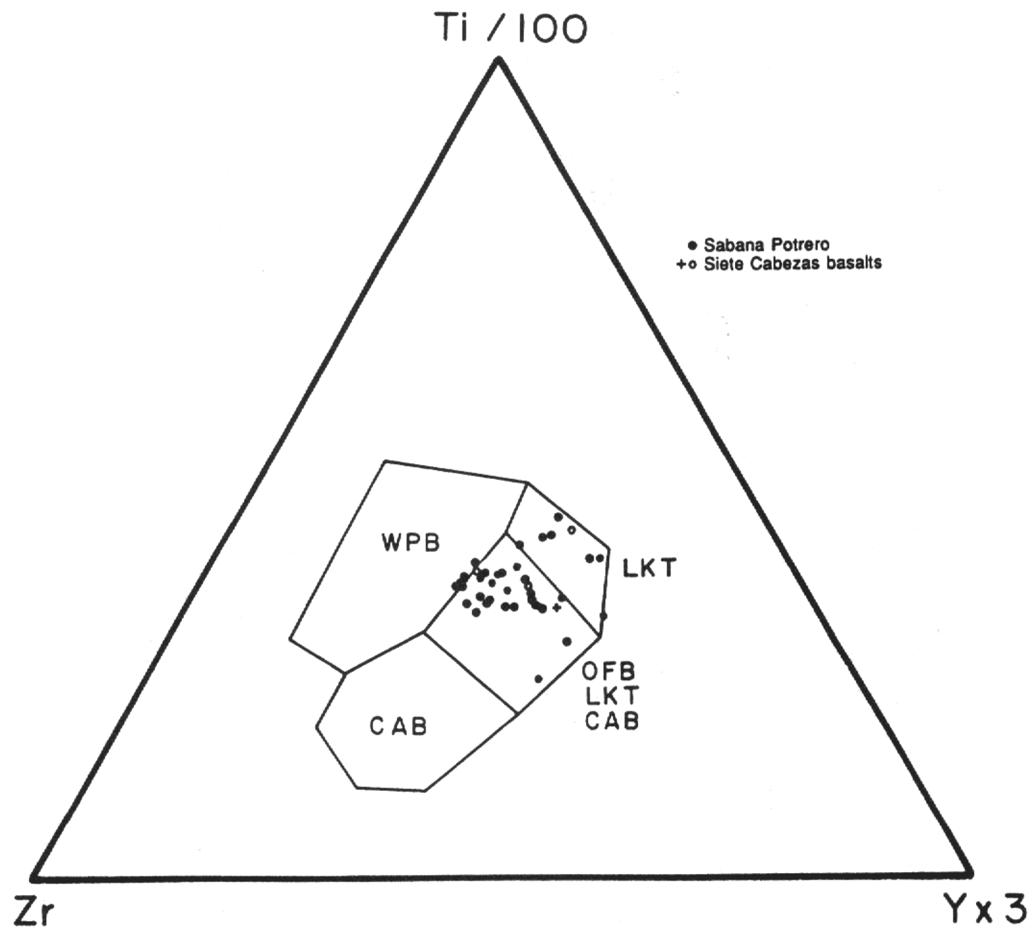

Fig. 7 Ti-Y-Zr plot (after Pearce and Cann, 1973) for the basaltic rocks from the Sabana Potrero area. OFB = ocean floor basalts; LKT = low potassium tholeiites; WPB = within plate basalts; CAB = calc-alkaline basalts.