Cenozoic alkalibasaltic to ultrabasic volcanism in the uppermost Magdalena Valley, Southern Huila Department, Colombia

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ABSTRACT

The volcanic edifices in the San Agustín, San José de Isnos, La Argentina, Oporapa - San Roque and Acevedo areas in the southern part of the Huila Department mainly consist of lavas and pyroclastics, which according to chemical analyses vary in composition betwen alkali olivine basalt and mafitic nephelinite. Two volcanoes emitted tholeiitic andesites. Chemical composition indicates an upper mantle origin for the alkalibasaltic magma. Geochronological and morphological data suggest this volcanism to have culminated in the Pliocene or Pleistocene. The position of this new volcanic province to the East of, and parallel to the main andesitic volcanic chain of the Central Cordillera suggests that the fracture zones enabling the ascent of the magma from the mantle are somehow related to the subduction process.

RESUMEN

Los edificios volcánicos de las zonas de San Agustín, San José de Isnos, La Argentina, Oporapa-San Roque y Acevedo en el Sur del Huila consisten principalmente de lavas y piroclásticos que según análisis químicos varían en composición entre basaltos alcalinos olivínicos y nefelinitas mafíticas. Dos volcanes emitieron andesitas toleíticas. La composición química indica que el magma alcalibasáltico se originó en el manto superior. Dataciones isotópicas y características morfológicas sugieren que el volcanismo alcalibasáltico culminó en el Plioceno o Pleistoceno. La extensión de este nueva provincia volcánica el Este del cinturón volcánico andesítico de la Cordillera Central y paralelo al mismo, hace suponer que las fracturas que permitieron el ascenso del magma desde el manto están relacionadas en alguna manera con el proceso de la subducción.

INTRODUCTION

Cenozoic volcanism in the Colombia Andes takes place from the Miocene onward from vents in the highest part of the Central Cordillera, the Cauca-Patía depression and in the southernmost part of the Western Cordillera. Andesitic and dacitic compositions predominates, as shown e. g. in the Ruiz - Tolima complex (JARAMILLO, 1980), the Puracé volcano (KURODA & PARIS, 1978; Fig. 1) and other volcanoes in SW Colombia (MURCIA & MARIN, 1981). Rhyolitic obsidian was reported from near the Sotará volcano (MANJARRES & NICHOLLS, 1958) and large volumes of rhyolitic ignímbrites were deposited in the area presentely under study, the Uppermost Magdalena Valley,

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possibly from the Cutanga Caldera (KROONENBERG, *et al.*, 1981). Although the westernmost volcanoes developed on oceanic crust and the volcanoes in the Central Cordillera on continental crust, no clear W-E trends in major element geochemistry of the constituing volcanic rocks have been detected so far (MURCIA & MARIN, 1981). The slight Si, K and Rb enrichment from south to north, noted by Murcia & Marín (1981) is counterbalanced by the occurrence of rhyolites in the south and their absence in the north.

In this paper a new volcanic province will be described to the east of the Central Cordillera, which differs significantly from the provinces known up to now, not only in the much more continentwards location of its vents (Fig.1), but also in its much more basic composition and different eruption style.

The occurrence of basaltic rocks in the area was first noted by BERGT (1899) through petrographic study of statues of the San Agustín archeological area and of some pebbles collected by Stübel in 1862. TELLO & HERNANDEZ (1976) were the first to recognize the presence of volcanic cones in the same area; they described the constituent rocks as andesites. KROONENBERG, *et al.* (1981) first established the clearly basaltic character of these volcanoes and found many eruption centres. The present study results from photointerpretation and field work by the first and the third author while teachin postgraduate photogeology courses at the Centro Interamericano de Fotointerpretación, Bogotá, Colombia, complemented with petrography by the first and the second author, and chemical analyses by the second author in the Mineralogisch-Petrologisches Institut of Tübingen University, Western Germany.

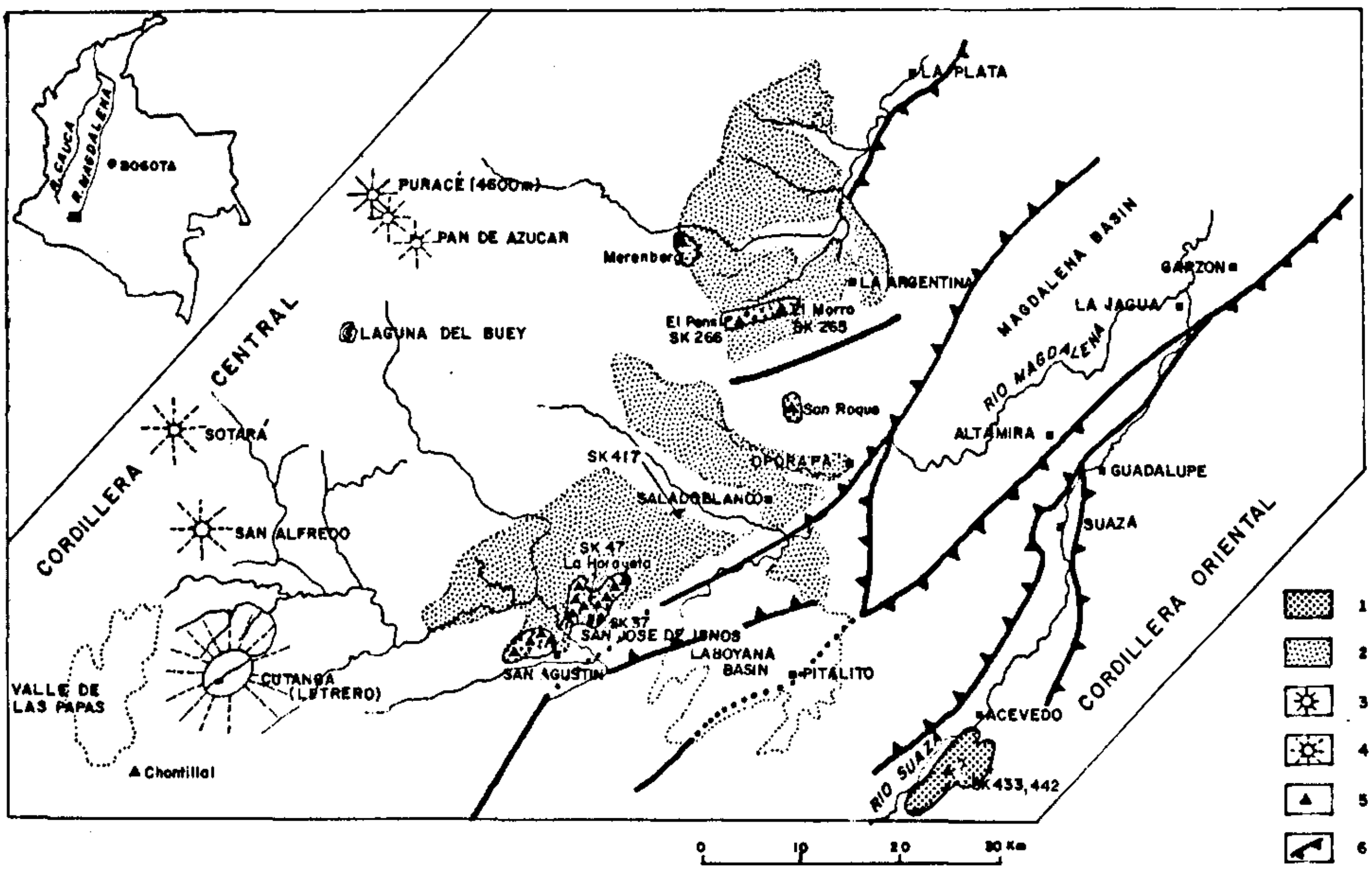

FIG. 1. Location of the alkalibasaltic volcanic province of the Uppermost Magdalena Valley. Lenged: 1. Alkalibasaltic and related rocks. 2. Rhyolitic ignimbrites. 3. Active stratovolcano. 4. Extinct stratovolcano. 5. Small cone. 6. Main border faults of the Magdalena Basin; ticks point to upthrust direction. Sk 433: Location of analysed sample.

GEOLOGICAL SETTING

The geology of the uppermost Magdalena Valley was recentely described by KROONENBERG & DIEDERIX (1982). The main morphostructural elements are the Central Cordillera, the Magdalena Basin and the Eastern Cordillera. Both Cordilleras are underlain by Precambrian-Jurassic crystalline rocks, as shown by extensive outcrops in upthrusted blocks in the area. In the southernmost part of the area the two cordilleras converge to form the Central - Eastern Cordillera, but the individual components are still recognizable far south. The Central Cordillera has been a positive feature since the Caledonian Orogeny. Shallow - marine Cretaceous sediments and, after a period of uplift, Tertiary molasse deposits were laid down to the east of it.

The beginning of Cenozoic volcanism is evidenced by volcaniclastic components n the molasse deposits of the Miocene Honda Formation and the Mio-Pliocene Gigante Formation, as well as by thin dacitic pumice flows in the latter formation that were dated by VAN HOUTEN (1976) at 8.5 ± 0.4 m.y.

Cretaceous and Tertiary deposits were folded and faulted along high angle reverse faults at the end of the Pliocene during a major orogenic event, during which the Eastern Cordillera was uplifted. The orogenic paroxysm at the end of Pliocene was accompanied by a dramatic increase of volcanism in the Central Cordillera. Hundreds of metres of torrential volcaniclastic conglomerates, lahar - type andesitic volcanic breccias and rhyolitic ignimbrites were laid down on both sides of the Central Cordillera. The increase of mudflows as compared with older deposits may testify to the uplift of the Central Cordillera to above the snow line and of the beginning of Pleistocene glaciation. The oldest postorogenic volcaniclastic terrace deposits at Paicol in the same area were dated by VAN HOUTEN (1976) at 3.7 ± 0.2 ma.

BASALTIC-ULTRABASIC VOLCANOES OF THE UPPER MAGDALENA VALLEY

(1) San Agustín - San José de Isnos area (Fig. 1)

TELLO & HERNANDEZ (1976, see also HERNANDEZ & TELLO, 1978) identified five volcanic cones in this area, and eight more were found by KROONENBERG, *et al.*, 1981. All volcanoes are small conical edifices, not exceeding 1-2 km in diametre and protruding about 100-150 m above the surrounding ignimbrite plain at 1750 m above sea level. They are usually deeply eroded, and weathering commonly reaches depths of over 10 m. Only occasionally fresh rock is encountered in road cuts. In a few instances remains of a crater can be discerned, not exceeding 400 m in diametre.

The Horqueta volcano has a less weathered appearance, and may represent one of the younger edifices in the area. A roadcut in this volcano shows alternating layer of lapilli and small bombs. The crater rim of the Alto de los Idolos is an important archeological site; basalts were used for tombstones and statues here, as well as ignimbrites (BERGT, 1899; TELLO & HERNADEZ, 1976).

(2) La Argentina area

The second most important area is situated in the La Plata Basin at 30 km SW from the town of La Plata. Three volcanic centres have been found here. The Merenberg volcano at 2500 m has a swampy caldera 1,5 km in diametre, the rim of which only projects 100 m above the surrounding ignimbrite plain. Andesitic lava flows have been emitted mainly towards the notheast. The El Pensil volcano at 2000 m, shows a low crater rim breached towards the north by a short lava flow. Another of andesitic composition was issued towards the east, filling a valley eroded in the Ignimbrites. Two small cones have been found between the Merenberg and El Pensil volcanoes, thus defining a short NW lineament. These forms are much fresher than the basaltic volcanoes of San Agustín - San José de Isnos. The third volcano, El Morro, is a perfectly fresh scoria cone about 100 m in height at about 1800 m above sea level. A roadcut shows alternating layers of fresh lapilli and small bombs. The El Morro cone is situated on top of the eastern andesitic lava flow of the El Pensil Volcano.

(3) Oporapa - San Roque area.

A deeply weathered volcanic cone, similar to those of San José de Isnos, was found at 2000 m on the southern side of the Serranía de las Minas, near San Roque, Municipio de Oporapa. No fresh rock outcrops have been found, but columnar joint blocks of basaltic lavas are found along the slopes and in the streams that drain the area. A basalt pebble from the Q. El Guayabo, was described petrographically by BERAT, (1899). A second cone further west was identified in the aerial photographs.

(4) Acevedo area

Between Acevedo and San Adolfo in the Suaza Valley at the western flank of the Eastern Cordillera a thick basaltic lava valley fill has been found at an altitude of 1700-1200 m above sea level. The basalt is deeply weathered and shows the same topography of small convex hills as the ignimbrite plain further to the west. No volcanic vent could be identified, neither in the aerial photographs nor in the field, probably due to strong weathering and erosion. Rock outcrops are few, and rarely completely fresh. Fresh material for analyses has been taken from a block field which probably representes an old landslide deposit.

PETROGRAPHY

The dominant petrographic festures of this volcanic province are the abundance of olivine and augite, and the absence of plagioclase phenocrysts. Three rock types have been distinguished.

1. **Alkali olivine basalts** and related rocks are the main rock types in the San Agustín, San José de Isnos and Oporapa - San Roque areas and of the El Morro cone in the La Argentina area. They contain abundant phenocrysts of olivine with yellow "iddingsitic" bordes and strongly zonary augite, set in a matrix in which augite predominates over tabular intermediate plagioclase and with magnetite/ilmenite and usually some glass. According to the Rittmann norms (Table 1, cf, below), two samples are alkali olivine basalts, whereas two other ones contain appreciable normative nepheline and are classified as mela - tephriphonolite and nephleline basanite, although no feldspathoids have been identified petrographically.

2. **Ultrabasic lavas** form the bulk of the Acevedo valley fill and occur at one site in San José de Isnos. Their phenocrysts are olivine and augite similar to those of the alkali olivine basalt, but the groundmass does not contain tabular plagioclase. Some interstitial untwinned plagioclase occurs between abundant augite and opaque in the Acevedo rocks, next to tiny biotite flakes and some secondary carbonate. A few peridotite (e. g. spinel wehrlite) nodules have been found in these lavas. According to the Rittmann norm (SK433, Table 1) they correspond to mafitic nephelinites, but no feldspathoids have been detected microscopically. Sample SK 38 from San José de Isnos (not analysed) consists of olivine phenocrysts and augite (micro) phenocrysts only, set in a brown glassy groundmass without any feldspar. Apatite is the commonest accessory in both alkali basalts and ultrabasic lavas.

3. **Andesites.** The rocks of the El Pensil (SK 266) and Merenberg volcanoes contain only sparse ferromanesian phenocrysts (olivine and augite at Merenberg and orthopyroxene at El Pensil), set in a pilotaxitic matrix of tabular plagioclase with minor augite and opaque minerals. Although these rocks are andesites on account of their low colour index, they resemble the preceding rock types in the absence of plagioclase phenocrysts. Quartz xenocrysts and quartz-rich xenoliths surrounded by augitic reaction rims have been found in the andesites as well as in some alkali olivine basalts.

MAJOR ELEMENTS CHEMISTRY

Chemical analyses of six samples are given in Table 1, together with the calculated Rittmann norms. Their calculated composition is plotted in the double Streckeisen triangle in Figure 2. Two rock suites are discernible; C 81, C 83, C 77, C 78, C 79 belong to the **alkalibasaltic suite**, partly with strong undersaturation on account of their low SiO_2 content (C 81). Part of the rocks show high contents of mafic minerals (C 81, C 83), on account of high levels of MgO,Fe total and CaO. The TiO_2 content is normal for the alkalibasaltic suite, but the P_2O_5 contents are unusually high. These samples are very similar to the Miocene alkalibasalt suite of the Vogelsberg area in Western Germany (Hessen). This is a typical continental cratogenic volcanic region, bounded by the northern continuation of the Rhine graben faults. The differences in chemical composition between the samples are only in part caused by differentiation processes (C 81 is an example of strong enrichment of mafic minerals by gravitative differentiation). However, the main cause of these differences may be varying degrees of partial melting at different P-T conditions at different levels of the upper mantle.

There is a second suite corresponds to the **tholeiitic basaltic suite** (C 80). This type should not be regarded as a member of the calcalkaline andesitic suite on account of chemical differences, e. g. the higher P_2O_5 content compared with the calcalkaline andesites of the south-Colombian volcanoes, which range between 0.1 and 0.2 %al the same

Laboratory Number	C 81	C 83	C 77	C 78	C 79	C 80
Fiel Number	SK 433	5-11-81/2	SK 37	SK 47	SK 265	SK 266
SiO_2	40,19	42,94	43,92	44,67	49,57	59,82
TiO_2	2,46	2,12	2,04	1,83	1,19	0,79
Al_2O_3	10,23	11,93	11,95	13,01	14,49	16,78
Fe_2O_3	12,27	11,64	11,42	10,95	9,67	5,56
FeO						
MnO	0,13	0,13	0,13	0,14	0,11	0,08
MgO	14,78	12,41	10,72	11,41	10,29	3,94
CaO	13,59	13,44	11,30	11,27	9,55	5,03
Na_2O	3,10	3,43	3,65	1,74	3,52	4,75
K_2O	1,57	2,11	0,74	0,77	1,10	2,00
P_2O_5	1,33	1,14	1,03	0,89	0,51	0,33
H_2O	0,97	0,09	1,92	3,38	0,56	0,70
Total :	100,40	99,37	98,80	100,05	100,56	99,78
RITTMANN NORMS						
Quartz	--	--	--	--	--	8,4
Sanidine	--	14,2	2,7	2,2	4,1	11,5
Plagioclase	0,6	10,5	33,3	47,6	54,9	63,5
Nepheline	15,2 *)	15,3	9,3	--	1,1	--
Clinopyroxene	52,5	37,2	33,9	23,4	20,8	3,5
Orthopyroxene	--	--	--	7,4	--	10,3
Olivine	20,3	17,8	15,6	14,3	15,7	--
Ore minerals	1,7	2,2	2,7	3,0	2,4	2,0
Apatite	3,1	2,6	2,4	2,1	1,1	0,7
Total :	99,9	99,8	99,9	99,9	100,1	99,9
Colour Index	74,5	57,2	52,2	48,1	38,8	15,9
Rock name	Mafitic nepheli-nite	Mela-tephri-phonolite	Nepheline basanite	Alkali olivine basalt	Alkali olivine basalt	Quartz-tholeiite mugearite (=tholeiitic andesite)

*) plus 6,5 Leucite

TABLE 1. Chemical analyses and Rittmann norms of volcanic rocks from the uppermost Magdalena Valley. Sample localities: SK433, east bank of Suasa river, road from Acevedo to Vereda El Rosario, 3 km S of Acevedo. 5/1/81-2 road from San Agustín to San José de Isnos, 6 km San José de Isnos. SK 37 Lava flow roadcut 5 km S of S. José de Isnos. SK 47 Bomb La Horqueta volcano, roadcut 4 km W of S. José de Isnos. SK265 Bomb El Morro, roadcut La Argentina-El Pensil 6 km W of La Argentina. SK 266 Lava flow El Pensil volcano, roadcut 5 km W of La Agentina.

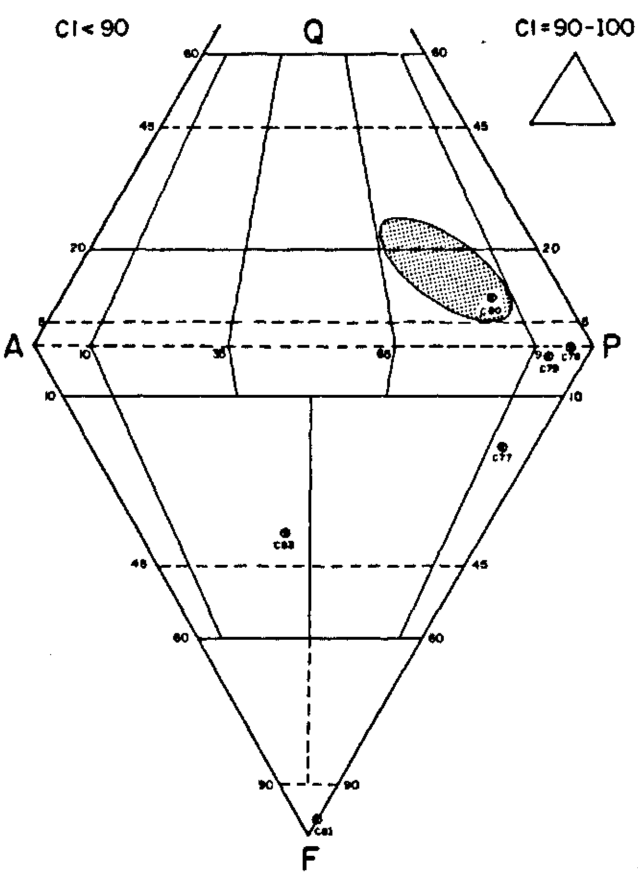

FIG. 2. Strecheisen plot of Rittmann norms of analysed sample. Dotted field represents compositional range of Cenozoic volcanics of the southern and central Colombian Andes.

SiO_2 content (about 60%). With the higher P_2O_5 contents these rocks have a tendency to join the alkalibasaltic suite. These rocks probably originated at higher levels of the mantle under lower P-T conditions.

AGE

A sample of the alkalibasaltic suite (a mafitic nephelinite similar to C 81 from the same location) has been dated by K-Ar whole-rock method by Geochron Laboratories, Cambridge, USA. The sample was pretreated with diluted with dilute HF an HNO_3 to remove alterations, and analysed in duplicate. The results are given in Table 2. The age obtained of 31.2 ± 2.7 Ma (Oligocene) is very high in view of the morphological characteristics of the valley fill and in view of the absence of geological evidence for pre-Miocene volcanism in this part of the Andes. An anomalous high age due to excess radiogenic argon cannot be excluded, as such phenomena are known to occur even in Quaternay basaltic lavas (OBRADOVICH *in* NAESER, *et al.*, 1981).

An Upper Miocene maximum age for the alkalibasaltic volcanism in the San José Isnos - San Agustín area is indicated by the rhyolitic ignimbrites underlying these volcanoes (Table 2). Morphologically the perfect scoria cone of El Morro may even be Holocene. The combined evidence suggests that alkalibasaltic and tholeiitic volcanism took place mainly in the Pliocene - Pleistocene.

TECTONIC SIGNIFICANCE

The alkalibasaltic composition and the occurrence of spinel-peridotite nodules strongly suggest a mantle origin for these magmas. On the other hand, andesitic magmas in the Northern Andes probably result from partial melting of subducted oceanic crust (HÖRMANN & PICHLER, 1982), and the rhyolitic magmas extruded as ignimbrites may have resulted from partial anatexis of older continental crust and/or subducted sediments. The occurrence of alkalibasaltic volcanics, usually associated with rifts, in close spatial and temporal association with typical subduction-zone andesitic to rhyolitic volcanics is difficult to explain.

A structural control of the location of the vents is not very evident. The Acevedo, San Roque and La Argentína volcanic areas might define a NW lineament parallel to those defined by the Puracé - Pan de Azúcar volcanoes and the Sotará - Cutanga volcanoes (Fig. 1), but the main volcanic area of San Agustín - San José de Isnos does not fit into this pattern, and the strong differences in chemistry and mineralogy do not favour a common tectonic control for the andesitic and alkalibasaltic volcanism.

It seems more probable that the alkalibasaltic volcanic province continues in a direction parallel to and east of the main andesitic volcanic are of the Central Cordillera, as KÜCH (1892: 88) describes similar basalts with a SiO_2 content of 46.45 from the Cerro Campanero East of the Laguna La Cocha, 120 km SW of San Agustín, and as similar volcanic edifices have been identified photogeologically in the intervening area along the eastern slopes of the Central-Eastern Cordillera in the Mandiyaco-Villalobos area (Upper Caquetá Basin), DIEDERIX, *et al.* (1982) and further south in the Guamués area (Upper Putumayo Basin), FRANCO (1981). This distribution

Sample Method	rad.^{40}Ar ppm	rad.^{40}Ar/tot.^{40}Ar	Ave rad.^{40}Ar ppm	% K	Ave.%K	^{40}K, ppm	rad.^{40}Ar/^{40}K	AGE
SK 442 WR	.000672 .000607	.216 .292	.000640	.291 .278	.285	.347	.001842	31.2±2.7Ma
SK 417 Biot	.003002 .003346	.213 .204	.003174	6.196 6.232	6.214	7.581	.000419	7.1±0.3Ma

TABLE 2. K-Ar ages of volcanic rocks of the uppermost Magdalena basin. SK 442 mafitic nephelinite, E bank of Suaza river road Acevedo - Vereda El Rosario, 3 km S of Acevedo. SK 417 rhyolitic ignimbrite, road La Laguna Salto de Bordones, 2 km W of La Laguna.

suggests that the fractures that enabled the ascent of the alkalibabasaltic magmas from the mantle are somehow related to the subduction process, although the magma formation in itself seems to be independent from it. Less undersaturated alkali basalts occur in a similar tectonic setting east of the main volcanic chains of Central America (WEYL, 1980) and in the Basin and Range Province, USA (LEEMAN and ROGERS, 1970). Extrusion probably was penecontemporaneous with the most important event of compressional deformation and uplift since the Jurassic (KROONENBERG & DIEDERIX, 1982), corroborating a relationship between subduction and deep faulting. Further research in needed to elucidate this relationship.

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