Geofísica Internacional (1994) Vol. 33, Num. 1, pp. 67-77

Geochronologic contributions to the Tertiary sedimentary-volcanic sequences ("Baucarit Formation") in Sonora, Mexico

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Received: February 4, 1994; acepted: May 3, 1994.

RESUMEN

Fechamientos radiométricos por el método K-Ar, en flujos de rocas volcánicas intercaladas y suprayacientes a conglomerados volcanogénicos y areniscas de origen continental en Sonora, México, arrojan edades comprendidas entre 33 y 5 m.a. Entre éstas, las rocas volcánicas asociadas con conglomerados y areniscas conocidos como "Formación Baucarit" varían en edad desde los 23 a los 10 m.a.

Los estratos del Oligoceno-Mioceno medio contienen flujos de rocas volcánicas de composición basáltica, andesítica y andesítico-riolítica. Un pulso de magmatismo silícico a nivel regional ocurrió entre 14 y 10 m.a. Las secuencias del Mioceno superior hasta el Pleistoceno se asocian fundamentalmente con vulcanismo basáltico.

El proceso de extensión de la corteza es posterior a la deformación Larámide y posiblemente se inició en Sonora en el Eoceno tardío (?), seguido por la acumulación de conglomerados sintectónicos y flujos volcánicos del Oligoceno (33 a 24 m.a.). Este proceso fue aparentemente continuo a través del Terciario; no obstante, un período corto de deformación estructural distensiva ocurrió entre los 10 y 9 m.a. Este evento tectónico puede ser el responsable de la fisiografía actual de la Sierra Madre Occidental ("Provincia de Sierras y Valles Paralelos") en Sonora, México.

PALABRAS CLAVE: Baucarit, extensión, sintectónico, magmatismo.

ABSTRACT

K-Ar dating of volcanic flows underlying, intercalated with and overlying volcanogenic conglomerates and sandstones of continental origin in Sonora yielded ages from 33 to 5 m.y. Among these, volcanic rocks associated with conglomerates and sandstones known as the "Baucarit Formation" range in age from 23 to 10 m.y. The Oligocene and middle Miocene strata contain basaltic, andesitic and andesitic-rhyolitic volcanic flows. A peak of silicic magmatism occurred between 10 to 14 m.y. The upper Miocene through Pleistocene sequences are associated with fundamentally basaltic volcanism.

Crustal extension succeeded the cessation of the Laramide Orogeny, and may have begun in Sonora in the latest Eocene (?), followed by the initial accumulation of Oligocene syntectonic conglomerates and volcanic flows (33 to 24 m.y. old). Extension was apparently continuous through most of the Tertiary; nevertheless, a major, but short episode of extensional structural deformation occurred between 10 and 9 m.y. This tectonic event may be responsible for the actual physiography of the Basin and Range Province in Sonora.

KEY WORDS: Baucarit, extension, syntectonic, magmatism.

INTRODUCTION

The main objectives of this paper are: (1) To present new geochronologic information for Tertiary continental sedimentary-volcanic sequences regarded as the "Baucarit Formation". (2) To describe the nature of volcanic activity that occurred during the deposition of some of these sequences.

The name "Baucari Division" was originally proposed by Dumble (1900) for conglomerates, sandstones and clayey sandstones with excellent bedding exposed in the vicinity of the town of Baucari, along the Cedros River in south-central Sonora, Mexico. In 1939, King conducted a more extensive and detailed geological study of the outcrops visited by Dumble. He changed the spelling to "Baucarit" and replaced the term "Division" with that of "Formation".

The Baucarit Formation, as defined by King (1939), consists of "slightly indurated, well-bedded sandstones, conglomerates and some clays. The conglomerates contain chiefly rounded to subangular fragments of the older volcanic rocks, but in places they include many of granite and some of limestone. In the lower part of the formation, where fully developed, there are one or more basalt flows interbedded with basalt agglomerate." The upper and lower members are distinguished by the presence of basalt in the lower part of the section, although King realized that when volcanic flows are absent, the distinction between the two members is difficult. With the exception of Radelli's paper (1986) in which he presented an analysis on the Basin and Range Province of Sonora, little attention has been given to these Tertiary sedimentary-volcanic successions other than indiscriminately using the term "Baucarit Formation", which is only a local lithostratigraphic designation for anything, anywhere in the state. We will commonly refer to the "Tertiary continental sedimentary-volcanic strata" when we mean to indicate the entire state, and occasionally to the "Baucarit Formation" for the type locality and strictly correlatable sections. In order to provide new insights into this issue, and to eliminate some of the misconceptions carried on for so many years, volcanic samples were collected for K-Ar dating from many of the localities studied by King and Dumble within Sonora's Basin and Range Province. Volcanic samples also were collected from places within the Parallel Ranges and the Sonoran Desert Provinces not visited by the above authors. This paper is neither intended to explain the origin of the Basin and Range Province nor to resolve the tectonic setting of northwestern Mexico given the fact that most field and geochronologic work remains to be done.

GEOCHRONOLOGIC RESULTS

Volcanic rock samples collected from different localities and stratigraphic levels associated with the conglomerates were dated using the K-Ar method. Sampling locations are shown in Figure 1. Isotopic results are shown in Tables 1-3. Analytical data are listed in Table 4.

EXTENSION AND SEDIMENTATION

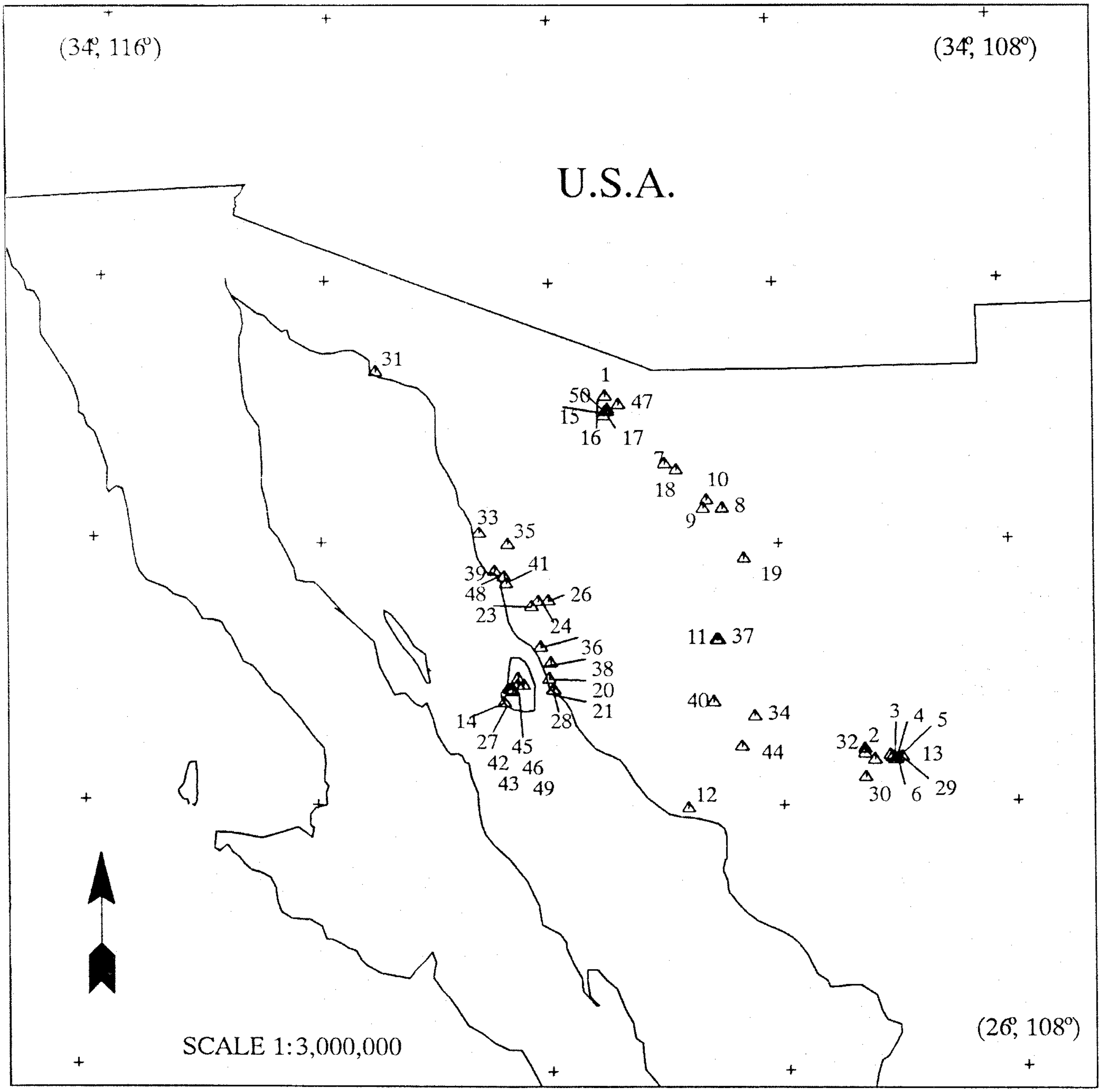
A good example of the intimate relationship between crustal extension, syntectonic sedimentation, and associated volcanism is provided by the Tertiary terrestrial sedimentary-volcanic assemblages (locally called Baucarit Formation) in Sonora. The major component of these sequences is conglomerate, with minor sandstone and claystone. The conglomerate is well-bedded to massive, poorly sorted, and primarily composed of various angular to subrounded volcanic fragments with fewer granitic and sedimentary clasts. However, the conglomerate in Rancho San Francisco, southeast of San José de Pimas, is composed exclusively of sedimentary fragments, including chert, siltstone, limestone and sandstone. The predominance of sedimentary clasts suggests the presence of a local sedimentary highland at that time. The depositional history of the conglomerates is solely continental. Sedimentation took place in alluvial-fan, fluvial, pediment, and lacustrine facies. The latter are represented by sandstones with excellent bedding and local concentrations of gypsum, salts, borax, zeolites, and limestone. The conglomerate displays, from outcrop to outcrop, various and complex internal depositional fabrics. These features include clast-and matrix-supported texture, sandy clay and tuffaceous matrix, granule and pebbly sandstone, and locally extreme coarseness. Pyroclastic horizons, tuffaceous lenses, or even ash-rich intervals are common. Sedimentary primary structures such as clast imbrication and cross-bedding rarely occur. Regarding fossils, only a few vertebrates have been reported from several localities.

The cementation processes of the Tertiary conglomerates are another unknown. The only available research on this aspect comes from Cocheme *et al.*, (1988), who proposed that the lithification of similar conglomerates in Cuenca El Huracán, Chihuahua was caused by zeolite crystallization. Zeolites apparently were derived from altered silicic volcanic material within the conglomerate subsequent to deposition. Further sedimentologic studies are needed.

The thicknesses of the sedimentary-volcanic piles are uncertain. Based on our observations, the thickest sections (in outcrop) occur in the eastern parts of the state, adjacent to the flank of the Sierra Madre Occidental within the Parallel Ranges. A 700 m-thick conglomerate and sandstone was reported by Roldan and McDowell (1992) between Tonichi and Onabas. In the west and central portions of the state, the thicknesses do not exceed 200 m. Ongoing geophysical research has established that the thicknesses of several basin fills are different in every single basin, and vary from a few hundred meters around Hermosillo to up to a couple of thousand meters along the coast of Sonora. The true sediment thicknesses accumulated during the subsidence of Tertiary basins will not be known until more geophysical and drill hole information are available.

TIMING AND NATURE OF VOLCANISM

Volcanic activity, although not volumetrically important (volcanic flows generally are few and thin) was intermittent throughout the sedimentation of the conglomerates and sandstones. Volcanic rocks 33 to 24 m.y. old (Table 1) are considered here pre-Baucarit Formation (sensu strictu), but they postdate the Laramide calcalkaline volcanism that ended at 35 to 40 m.y. as documented by many authors. Our data from volcanics associated with the conglomerates indicate a transition from Laramide compressive, calcalkaline volcanism to bimodal, extension-related basaltic, and rhyolitic-andesitic volcanism sometime in the early Oligocene at about 33 m.y. This type of volcanism continued through the Miocene with a peak of silicic magmatism from 14 to 10 m.y. as supported by the predominance of the rhyolite-ignimbrite suite (Table 2). The 11.6 and 12.8 m.y. ages (Bartolini *et al.*, 1991) for the ignimbrites that overlie conglomerates at La Colorada and Rancho San Francisco respectively, correlate in age with the 10.4 m.y.-old rhyolite-andesite association in the Sierra Lista Blanca (Morales *et al.*, 1990), and with the 12.6 m.y.-old rhyolite in the San José de Gracia area (Bartolini *et al.*, 1993). This geochronologic correlation is also extended to the 10 to 12 m.y.-old predominantly rhyolitic volcanism widespread along the coast, between Puerto Lobos and Bahía Kino (Gastil and Krummenacher, 1977), and with the 14 m.y. old ignimbrite interbedded with the Baucarit within the valley of the Río Yaqui between Tonichi and Onabas (McDowell and Roldan, 1991). In a regional perspective, this silicic magmatic pulse appears to be congruent with the later western phases of the rhyolite-andesite-calcic-latite series that erupted during the mid-Tertiary orogeny in southern Arizona (Damon, 1989). Oligocene-Miocene bimodal (rhyolite-andesite, basalt) magmatic suites changed to fundamentally basaltic. The volcanic transition may have occurred sometime in the latest Miocene considering the predominance of post-9 m.y. basalts (Table 3), the 8 m.y. old and younger basalts reported by Gastil and Krummenacher (1977) and the Plio-Quaternary basaltic fields in northern Sonora (Lynch, 1978), the Pinacate Volcanic Field (Lynch, 1981), Santa Ana's Comedores Formation (Salas, 1968) and the Moctezuma basaltic field (Paz, 1985).



1--UAKA-82022	2--UAKA-80009	3--UAKA-80013	4--UAKA-80013	5--UAKA-80013
6--UAKA-80014	7--UAKA-82021	8--UAKA-82024	9--UAKA-82024	10-UAKA-82025
11-UAKA-90060	12--1064	13-UAKA-80015	14--0933	15-UAKA-82120
16-UAKA-80112	17-UAKA-80112	18-UAKA-82023	19-UAKA-74157	20--1013
21--1081	22-UAKA-92020	23--1081	24--1081	25-UAKA-80016
26-UAKA-82048	27--1036	28--1079	29-UAKA-81038	30-UAKA-80017
31-UAKA-80056	32-UAKA-80010	33--0809	34-UAKA-81003	35--1810
36--1934	37-UAKA-92044	38--0975	39--0815	40-UAKA-80006
41--0914	42--1011	43--81014	44-UAKA-90033	45--1080
46--1000	47-UAKA-80042	48--1050	49--1012	50-UAKA-80111

Fig. 1. Map of Sonora showing the approximate locations of dated samples. Triangles represent volcanic and intrusive samples. The sample numbers listed in the map are the same as those listed in Tables 1-3. UAKA samples were obtained at the K-Ar Laboratory, University of Arizona, whereas non-UAKA samples were published by Gastil and Kummenacher (1977).

Table 1

Pre-Baucarit volcanics

Sample	Lat. (N)	Long.(W)	Locality	Rock Type	Mineral	Age (m.y.)
UAKA-82022	31° 0.8'	111° 30.1'	Rancho La Salada, Tubutama	Rhyolite	G	33.9 ±08
UAKA-80009	28° 25.3'	109° 18.7'	Mina La Olga, Yecora	Bas. Andesite	G	33.3 ±1.3
UAKA-80013	28° 21'	109° 4'	Road to Yecora, 2 km East of La Trinidad	Ashflow	P	31.9 ±0.7
UAKA-80013	28° 21'	109° 4'	Road to Yecora, 2 km East of La Trinidad	Ashflow	B	31.5 ±0.9
UAKA-80013	28° 21'	109° 4'	Road to Yecora, 2 km East of La Trinidad	Ashflow	S	31.2 ±0.7
UAKA-80014	28° 19.7'	109° 2.5'	North of Cerro El Bajío	Bas. Andesite	G	27.0 ±0.6
UAKA-82021	30° 37.7'	110° 59.8'	West of Río Magdalena near Fatima	Trachyte	G	24.4 ±0.6
INTRUSIVES THAT UNDERLIE CONGLOMERATES						
UAKA-82024	30° 16'	110° 29.1'	Cerro El Bajío, Cucurpe	Granite	H	26.3 ±0.8
UAKA-82024	30° 16'	110° 39'	Northwest of Cerro El Bajío, Cucurpe	Granite	B	27.6 ±0.6
UAKA-82025	30° 20'	110° 37'	Magdalena-Cucurpe Road	Ande. Porhyry	B	27.0 ±0.6
REWORKED ANDESITE BOULDERS IN CONGLOMERATE						
UAKA-90060	29° 16.6'	110° 32.7'	Cerro Prieto, San José de Gracia	Andesite	G	56.6 ±1.3

These basaltic magmas, in the majority of cases, postdate sedimentation, forming enormous, flat-lying mesas (malpaís).

CONGLOMERATES' STRATIGRAPHIC RELATIONSHIPS

The basal contact relations between the different conglomerates and older rocks are invariably unconformities. Basement rocks as old as Precambrian (NW Sonora) and granitic plutons as young as 27 and 27.6 m.y. old, are unconformably overlain by conglomerates near Cerro El Bajio in the vicinity of Cucurpe (Table 1). Knowing that the conglomerates are diachronous, unconformities are expected to be of different ages as well. Unconformities developed when basins began to fill with sediments and volcanics at different times and rates during the Tertiary. For instance, Baucarit conglomerates in the Yecora area (Cocheme and Demant, 1991) began to accumulate after 17 m.y., whereas conglomerates in San José de Gracia contain an interbedded 20 m.y. old basalt flow (Bartolini *et al.*, 1993).

REGIONAL STRATIGRAPHIC FRAMEWORK

Our reconnaissance studies of the Baucarit Formation in Sonora suggest some general stratigraphic relations. These relationships between different volcanic rocks and continental conglomerates are broadly depicted in the four stratigraphic columns of Figure 2.

(1) Post-Laramide, Oligocene terrestrial conglomerates underlain and interbedded by basalt and basaltic andesite flows.

(2) Miocene terrestrial conglomerates interbedded and/or overlain by rhyolite and bimodal (rhyolite-andesite, basalt) volcanic suites.

(3) Miocene marine strata with or without associated volcanics. These outcrops are confined to the coast of Sonora and Tiburón Island (Gastil and Krummenacher, 1977).

(4) Late Miocene through Pleistocene terrestrial conglomerates interbedded and overlain by flat-lying basalts (post-Baucarit).

We currently are studying the stratigraphy of the Baucarit Formation in detail, but it is not considered in this paper.

STRUCTURAL GEOLOGY

Data are not adequate to address in detail the structural geology of Tertiary continental strata in Sonora. So far, several stages of Tertiary structural extension have been proposed, but not quite constrained. Based on our limited number of ages, preliminary field data, and existing literature we primarily emphazise the following.

(1) Cenozoic crustal extension commenced in the latest Eocene (?), soon after the culmination of the Lara.

Table 2

Baucarit Formation (sensu strictu)

Sample	Lat. (N)	Long. (W)	Locality	Rock type	Mineral	Age (m.y.)
1064	27° 59'	110° 49.1'	North of Empalme	Basalt	P	23.8 ±1.3
UAKA-80015	28° 21.6'	108° 59.5'	West of Yecora, Río Mulato Valley	Bas. Andesite	G	23.2 ±0.5
0933	28° 54.3'	112° 32.3'	Southwest of Isla Tiburón	Andesite	P	22.7 ±1.1&
UAKA-82120	30° 59.3'	111° 31'	Arroyo La Salada, Tubutama	Bas. Andesite	G	22.6 ±0.5
UAKA-80112	31° 2.1'	111° 29.1'	Borax Deposit, Tubutama	Bas. Andesite	B	22.3 ±0.5
UAKA-80112	31° 2.1'	111° 29.1'	Borax Deposit, Tubutama	Bas. Andesite	G	21.5 ±0.5
UAKA-82023	30° 34.5'	110° 53.5'	Presa Pesqueira, Magdalena	Latite	G	21.9 ±0.5
UAKA-74157	29° 53'	110° 18'	San Felipe de Jesús	Bas. Andesite	G	21.8 ±0.5
1013	28° 59.3'	112° 2.75'	North of Bahía Kino	Andesite	H	21.0 ±0.8&
1081	28° 52.6	112° 0.08'	North of Bahía Kino	Dacite	B	20.8 ±5.7&
UAKA-92020	29° 16.5'	110° 32.6'	Cerro Prieto, San José de Gracia	Basalt	G	20.5 ±0.5
1081	30° 29.3'	110° 47.0'	North of Bahía Kino	Rhyolite	S	19.8 ± 0.4&
1081	30° 29.7	110° 50.2'	North of Bahía Kino	Andesite	WR	19.6 ±0.9&
UAKA-80016	28° 20.2'	109° 13.2'	North of Bahía Kino	Bas. Andesite	G	19.5 ±0.5
UAKA-82048	29° 34.5'	112° 1.2'	75 and 76 km markers, southeast of microwave	Rhyolite	S	18.8 ±0.4
1036	28° 54.3'	112° 32.3'	Southwest of Isla Tiburón	Andesite	H	18.3 ±2.4&
1079	28° 52.6	112° 0.1'	North of Bahía Kino	Dacite	H	17.8 ±0.8&
UAKA-81038	28° 23'	109° 18'	Northwest of Tepoca	Andes. Porphyry	H	17.2 ±0.4
UAKA-80017	28° 12.8'	109° 18.9'	3 km from Palmarito, along the road	Bas. Andesite	G	16.3 ±0.4
UAKA-80056	31° 15.0'	113° 32.8'	East of Puerto Peñasco	Bas. Andesite	G	15.1 ±0.4
UAKA-80010	28° 23.7'	109° 18.3'	Northwest of Tepoca	Bas. Andesite	G	14.0 ±0.3
0809	30° 5.7'	112° 37.8'	North of Bahía Kino	Andesite	P	14.0 ±3.0&
UAKA-81003	28° 41.3'	110° 14.2'	1.3 km southwest of Rancho San Francisco	Ignimbrite	S	12.8 ±0.3
1810	30° 0.7'	112° 22'	Rancho Golondrina	Dacite	F	12.7 ±0.4&
1934	29° 13.3'	112° 5.2'	Pico Demere	Rhyolite	P	12.7 ± 1.1&
UAKA-92044	29° 16.6'	110° 33.3'	Cerro Prieto, San José de Gracia	Basalt	G	12.6 ±0.3
0975	29° 6.0'	112° 6.8'	Sierra Seri	Andesite	P	12.3 ±2.9&
0815	29° 44.9'	112° 29.8'	Sierra Bacha	Rhyolite	WR	11.9 ±0.5&
UAKA-80006	28° 48'	110° 35.3'	Cerro La Colorada	Ignimbrite	S	11.6 ±0.4
0914	29° 45.2'	112° 48.3'	Sierra Bacha	Andesite	P	11.3 ±1.2&
1011	28° 53.9'	112° 32.0'	Southwest Isla Tiburón	Rhyolite	F	11.2 ±1.3&
81014	28° 59.9'	112° 29.2'	West Isla Tiburón	Andesite	P	10.9 ±2.3&
UAKA-90033	28° 27.4'	110° 21.3'	Sierra Lista Blanca	Andesite	P	10.4 ±0.2

Table 3

Post-Baucarit (sensu strictu) volcanics

Sample	Lat. (N)	Long. (W)	Locality	Rock type	Mineral	Age (m.y.)
1080	28° 56.4'	112° 26.7'	Central Isla Tiburón	Dacite	H	9.9 ±1.3&
1000	28° 48.5'	112° 24.8'	Southwest Isla Tiburón	Basalt	WR	7.0 ±0.3&
UAKA-80042	31° 4.0'	111° 23.0'	Cerro Prieto, Altar	Basalt	G	7.0 ±0.2
1050	29° 42.6'	112° 23.5'	Pozo Coyote, South Sierra Bacha	Basalt	G	6.4 ±1.9&
1012	28° 56.0'	112° 29.0'	West Isla Tiburón	Rhyolite	F	5.7 ±0.6&
UAKA-80111	31° 1.62'	111° 29.9'	Borax Deposit, Tubutama	Dacite	B	5.5 ±0.1

B-Biotite, H-Hornblende, S-Sanidine, P-Plagioclase concentrate, G-Groundmass (feldspar concentrate), M-Muscovite, F-Feldspars, WR-Whole rock. &-Gastil and Krummenacher, 1977

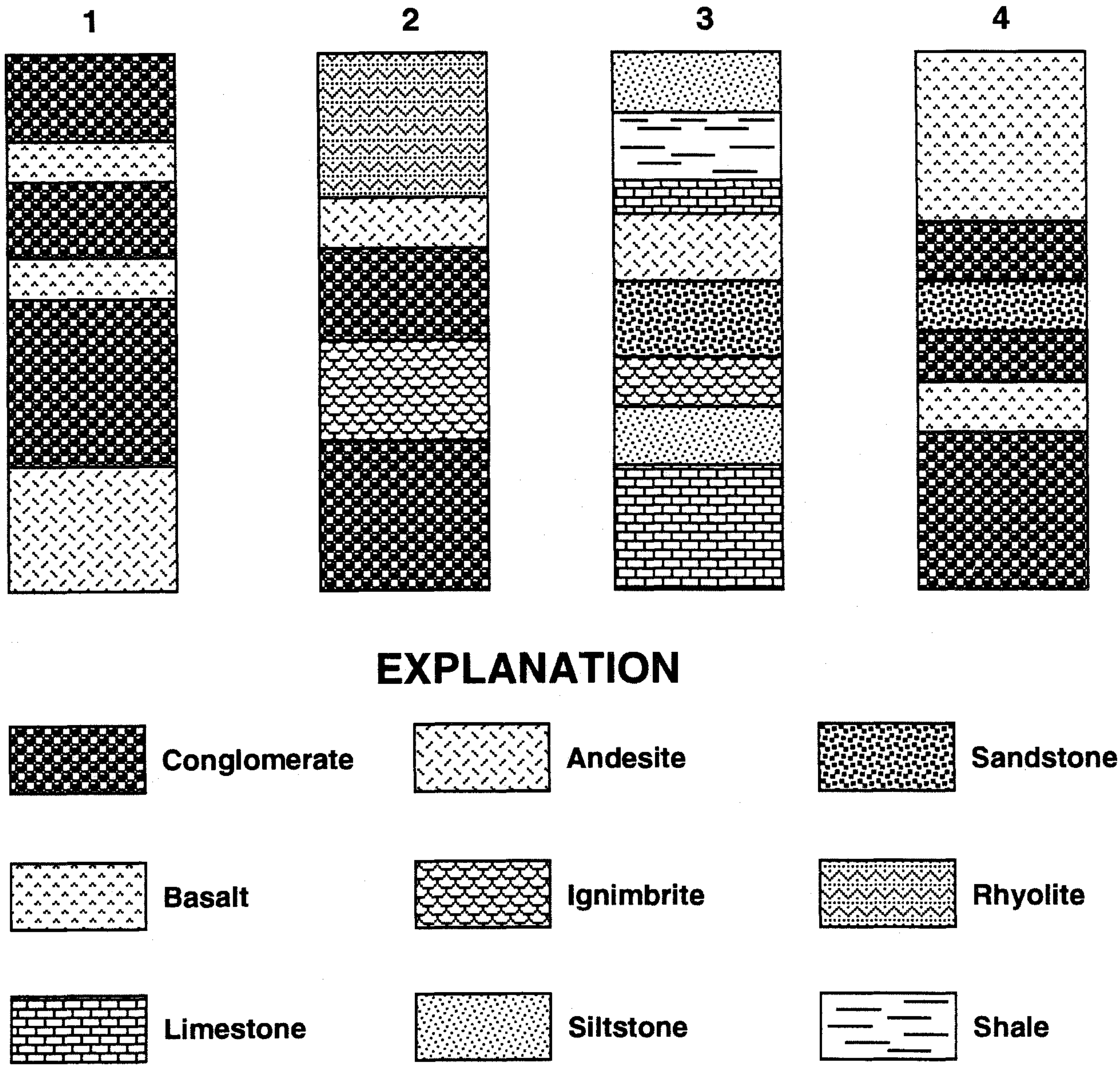


Fig. 2. Generalized stratigraphic columns of the Baucarit Formation. These schematic columns represent the very diverse relation-ships between volcanic rocks of different composition and continental, and marine sequences. No thicknesses are represented; columns are not at scale.

mide Orogeny, but prior to the emplacement of the first Oligocene volcanics and deposition of the conglomerates

(2) The majority of Tertiary strata are tilted. Tilting is both to the WSW and ENE reflecting a general E-W stress-orientation as previously proposed by numerous authors for Baja California, Sonora and Arizona.

(3) The tilting by faulting of volcanic rocks 10 m.y. old and older evidences a post-10 m.y. extensional block-faulting event. This event may be coeval with that described along coastal Sonora by Gastil and Krummenacher (1977), where all strata 10 m.y. old and older are involved in what they called Basin and Range-type tilting.

(4) No major deformation episode of extensional faulting occurred after 9 m.y. This statement is supported by the flat-lying nature of 9 m.y. old and younger volcanics (Table 3), and the 8 m.y. old and younger basalt flows in coastal Sonora (Gastil and Krummenacher, 1977). In addition, the Plio-Quaternary giant basaltic fields in Moctezuma-Tepache (Paz, 1985) and the Santa Ana Comedores Formation (Salas, 1968) are not tilted. Seemingly, no relevant extensional deformation has affected the 3.3 m.y. and younger San Bernardino basaltic volcanic field of Arizona and

Table 4

Analytical data

	% Potassium		Radiogenic Ar		% Atm. Ar		Reported		
	Data	Mean	Data	Mean	Data	Mean	Data	±	Err.
90060	2.663	2.639	259.7	263.0	6.4	5.3	56.6	±	1.3
Gm	2.580		266.2		4.6				
	2.570		267.0		4.5				
	2.690		259.2		5.8				
	2.692								
82022	5.618	5.647	335.4	335.3	11.8	13.7	33.9	±	0.8
Gm	5.655		333.9		11.6				
	5.687		335.2		11.5				
	5.628		336.0		11.4				
	5.647		336.7		11.5				
			339.9		16.3				
			331.6		16.4				
			337.8		15.9				
			332.5		16.3				
			333.8		11.6				
			335.5		16.2				
80009	0.411	0.410	23.34	23.91	70.0	69.1	33.3	±	1.3
Gm	0.410		23.86		69.5				
	0.409		24.54		67.7				
	0.410								
	0.412								
80013	1.716	1.705	95.70	95.23	6.9	7.1	31.9	±	0.7
Plag	1.705		94.50		7.4				
	1.695		95.50		7.0				
80013	6.100	6.108	334.0	337.0	47.8	47.5	31.5	±	0.9
Bio	6.102		335.1		47.7				
	6.092		341.8		46.9				
	6.140								
	6.107								
80013	8.862	8.825	483.4	481.0	3.9	3.2	31.2	±	0.7
San	8.826		478.5		2.4				
	8.833								
	8.774								
	8.828								
82024	6.060	6.060	293.4	292.0	15.1	13.8	27.6	±	0.6
Bio	6.007		291.5		13.4				
	6.069		291.7		13.5				
	6.106		291.9		13.5				
	6.058		291.7		13.5				
	5.981								
82024	0.434	0.435	19.94	20.0	42.4	41.9	26.3	±	0.8
Hbld	0.433		20.06		41.3				
	0.437		20.12		41.9				
	0.438		19.88		41.9				
82025	6.077	6.062	287.0	286.2	15.4	14.6	27.0	±	0.6
Bio	6.049		285.0		14.8				

	% Potassium Data	% Potassium Mean	Radiogenic Ar Data	Radiogenic Ar Mean	% Atm. Ar Data	% Atm. Ar Mean	Reported Data	±	Err.
	6.067		286.8		14.3				
	6.065		286.0		14.0				
	6.052								
80014	1.543	1.540	72.56	72.61	26.1	26.1	27.0	±	0.7
Gm	1.540		72.59		26.1				
	1.537		72.69		26.0				
82021	9.943	9.888	420.5	420.9	2.3	2.6	24.4	±	0.6
Gm	9.848		419.8		2.5				
	9.875		422.4		2.6				
	9.919		421.2		2.3				
	9.897		420.5		3.3				
	9.844								
80015	1.840	1.834	74.39	74.16	14.0	14.9	23.2	±	0.1
Gm	1.832		74.11		15.1				
	1.830		73.98		15.6				
	1.831								
	1.837								
82120	2.483	2.470	97.52	97.39	6.2	5.9	22.6	±	0.5
Gm	2.496		95.44		7.4				
	2.457		97.82		5.3				
	2.467		98.07		5.3				
	2.456		97.69		5.5				
	2.463		97.78		5.5				
80112	6.953	6.985	271.2	271.4	31.1	31.6	22.3	±	0.5
Bio	7.016		271.5		32.1				
80112	3.210	3.208	120.6	120.3	26.2	26.5	21.5	±	0.5
Gm	3.211		121.1		26.6				
	3.207		119.0		26.6				
	3.204		120.5		26.5				
82023	2.442	2.458	93.71	93.76	7.7	7.0	21.9	±	0.5
Gm	2.450		93.72		7.3				
	2.446		93.99		6.4				
	2.455		93.60		6.5				
	2.457								
	2.491								
	2.498								
	2.452								
	2.445								
	2.446								
74157	2.352	2.348	89.66	89.34	6.3	6.3	21.8	±	0.5
Gm	2.344		89.01		6.3				
92020	1.862	1.859	66.43	66.49	21.2	18.0	20.5	±	0.5
Gm	1.860		66.60		21.8				
	1.864		66.44		15.8				
	1.843		66.41		16.5				
	1.866		66.80		16.0				
			66.27		16.5				
80016	1.455	1.455	50.40	49.37	19.5	19.5	19.5	±	0.5
Gm	1.441		48.91		19.5				

	% Potassium		Radiogenic Ar		% Atm. Ar		Reported		
	Data	Mean	Data	Mean	Data	Mean	Data	±	Err.
	1.465		48.81		19.6				
	1.460								
82048	9.776	9.761	319.5	319.7	12.4	12.2	18.8	±	0.4
San	9.754		319.8		11.9				
	9.812		321.0		12.0				
	9.698		318.4		12.3				
	9.767		319.9		12.2				
81038	0.575	0.574	17.2	17.19	31.9	31.9	17.2	±	0.4
Hbld	0.572		17.18		31.8				
	0.582		17.12		32.0				
	0.580		17.22		32.0				
	0.570		17.31		31.9				
	0.568								
80017	1.777	1.768	49.37	50.21	34.1	33.5	16.3	±	0.4
Gm	1.770		50.48		33.7				
	1.760		50.79		32.9				
	1.765								
80056	1.260	1.263	32.76	33.12	25.1	24.9	15.1	±	0.4
Gm	1.265		33.20		24.8				
	1.266		33.40		24.6				
	1.261								
	1.262								
80010	2.306	2.331	56.59	56.68	14.6	14.4	14.0	±	0.3
Gm	2.348		56.78		14.1				
	2.336								
	2.329								
81003	4.275	4.251	93.54	94.31	28.8	28.5	12.8	±	0.3
San	4.246		93.89		28.8				
	4.243		95.49		28.0				
	4.238								
92044	4.609	4.565	98.90	99.65	22.1	20.5	12.6	±	0.3
San	4.570		99.70		20.5				
	4.542		99.80		20.8				
	4.557		100.2		19.1				
	4.552		99.50		20.3				
	4.572		99.80		20.0				
	4.556								
80006	2.298	2.282	46.22	46.11	36.7	31.5	11.6	±	0.3
San	2.266		45.63		30.3				
			45.62		30.4				
			46.95		28.6				
90033	0.332	0.345	6.339	6.227	50.4	51.6	10.4	±	0.4
Gm	0.334		6.268		51.0				
	0.359		6.074		53.3				
	0.339								
	0.342								
	0.350								
	0.356								

	% Potassium		Radiogenic Ar		% Atm. Ar		Reported		
	Data	Mean	Data	Mean	Data	Mean	Data	±	Err.
80042 Gm	1.223 1.221 1.224	1.223	14.90	14.90	56.9	56.9	7.02	±	0.18
80111 Bio	7.203 7.185	7.194	66.42 69.64 68.61	68.22	15.6 14.8 15.2	15.2	5.46	±	0.12

northern Sonora (Lynch, 1978), or the Pinacate Volcanic Field (Lynch, 1981). Recent fault movements like the one in Colonia Morelos and San Bernardino Valley, northern Sonora (Du Bois and Smith, 1980) are not precluded, however.

Faults that border some of the Baucarit basins are proposed to be younger than the faults that initially generated the basins in which the Baucarit was deposited (Radelli, 1989). This idea is certainly correct. Additional geochronology and structural field data will determine how block faulting is structurally and chronologically related to detachment faulting, which has already been recognized (but is poorly age-constrained), in the metamorphic core complex of Sierra de Mazatán (Anderson *et al.*, 1980), the Caborca region (DeJong *et al.*, 1988, DeJong *et al.*, 1990), and the metamorphic core complex of Magdalena (Nourse, 1990). It is necessary to determine how detachment faulting occurred and which conglomerates were affected.

CONCLUSIONS

Within the major limitations of our data and the virtual absence of detailed studies for constructing a reasonable regional synthesis, we summarize as follows.

(a) Isotopic ages of volcanic rocks associated with continental conglomerates within the Sonoran Basin and Range, Parallel Ranges and Sonoran Desert Provinces range in age from 33.9 to 5.0 m.y. Volcanic rocks younger than 23 m.y. are pre-Baucarit. Volcanic rocks 23 to 10 m.y. old interbedded and overlying the conglomerates are grouped into the so called "Baucarit Formation" (King, 1939, sensu strictu). Volcanics younger than 10 m. y. are considered post-Baucarit.

(b) The stratigraphic contacts between different conglomerates and older rocks are always unconformities. These unconformities are of diverse Tertiary ages from place to place.

c) Volcanic transitions from Laramide calcalkaline magmas to bimodal basaltic and andesite-rhyolite suites that formed under an extensional tectonic setting appear to have occurred in the early Oligocene (as evidenced by volcanics linked to the conglomerates). This type of volcanism continued until the end of the Miocene. In the Miocene, a peak of silicic magmatism is known from 10 to 14 m.y. Finally, a change from bimodal to fundamentally basaltic volcanism occurred in the late Miocene, not earlier than 9 m.y. ago.

(d) Initial crustal extension must have been initiated prior to the formation of the oldest conglomerate and volcanics (33 m.y. old) that is, in the latest (?) Eocene. A short but intense period of normal faulting can be bracketed between 10 and 9 m.y. ago. Volcanic rocks and conglomerates 10 m.y. old and older are tilted and uplifted by NNW-SSE trending normal faults, whereas 9 m.y. old and younger volcanic rocks and conglomerates remain practically undeformed.

ACKNOWLEDGMENTS

Most of the geochronologic data were provided by the K-Ar Laboratory of the Geosciences Department at the University of Arizona, Tucson, Arizona. Partial funding for isotopic dating to Professor Mariano Morales (University of Sonora) was awarded by Conacyt. Carlos Montana plotted our data using Interleaf.

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