

STRATIGRAPHY OF THE LOWER CRETACEOUS CINTURA FORMATION, SIERRA EL CHANATE, NORTHWESTERN SONORA, MEXICO

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ABSTRACT

The Lower Cretaceous Cintura Formation is described and defined as a stratigraphic unit for northwestern Sonora, Mexico. The reference sections are in the Sierra El Chanate, located about 20 km northeast of Caborca. This unit is described for the first time in the Caborca-Altar area. Four sections were measured and described. Its maximum thickness is 319 m in the northern side of the sierra, decreasing to 170 m in the southern side.

The Cintura Formation consists of red to purplish-red mudstone and shale, and minor gray and reddish to purplish-gray sandstone. The basal contact is sharp to transitional with the Arroyo Sásabe Formation, whereas the upper one is unconformable (erosional to angular) with the Pozo Duro formation of the Late Cretaceous El Chanate Group.

The Cintura Formation has been reported in northeastern Sonora and southeastern Arizona as part of the Bisbee Group. The presence of the Cintura in this part of Sonora is important, because it documents a westward extension of the Early Cretaceous Bisbee basin as far as Caborca.

The Cintura Formation of the Sierra El Chanate was deposited in a tidal flat to fluvial-flood plain environment. This unit represents the regressive phase of the Bisbee Group, which had its maximum sea advance during Mural and/or Arroyo Sásabe times. At the end of Bisbee time, the sequence was probably folded, eroded, and covered by the coarse clastic sediments of the El Chanate Group.

Key words: stratigraphy, Lower Cretaceous, Sonora, Mexico.

RESUMEN

Se describe la Formación Cintura, del Cretácico Inferior, como unidad estratigráfica para el noroeste de Sonora, México. Esta unidad se encuentra bien expuesta en la sierra El Chanate, localizada a unos 20 km al noreste de Caborca. Se midió y describió cuatro secciones estratigráficas. El espesor máximo es de 319 m, en el flanco septentrional, disminuyendo a 170 m, en el lado meridional.

La Formación Cintura está formada por lodolita y lutita de color rojo a rojo violáceo, y arenisca de colores gris a gris violáceo y verde. El contacto inferior es concordante, de abrupto a transicional, con la Formación Arroyo Sásabe; mientras que el contacto superior es una discordancia erosional a ligeramente angular con la formación Pozo Duro del Grupo El Chanate.

La Formación Cintura ha sido descrita en la porción nororiental de Sonora y sudoriental de Arizona como parte del Grupo Bisbee; su localidad de descripción original se encuentra en las Montañas Mule, cerca de Bisbee, Arizona. La presencia de la Formación Cintura en el área de Caborca representa la extensión de la cuenca Bisbee, del Cretácico Inferior, hacia el oeste.

La Formación Cintura de la sierra El Chanate se depositó en una planicie de mareas a aluvial. Esta unidad representa la fase regresiva del Grupo Bisbee, cuyo máximo avance se registra con la Caliza Mural y/o la Formación Arroyo Sásabe. Al finalizar el depósito del Grupo Bisbee, hubo un levantamiento tectónico, evidenciado por erosión, y el depósito de sedimentos gruesos del Grupo El Chanate.

Palabras clave: estratigrafía, Cretácico Inferior, Sonora, México.

INTRODUCTION

The Cintura Formation in the Sierra El Chanate (Figure 1 and Plate 1) was first described by Jacques-Ayala (1983, p. 32) as the upper member of the Sásabe formation, which was renamed as Arroyo Sásabe formation by Jacques-Ayala and Potter (1987, p. 204). The Arroyo Sásabe formation was identified by Jacques-Ayala and others (1990b) as the Bisbee Group of northeastern Sonora and southeastern Arizona. Therefore, the lower and upper members were renamed as the Morita and Cintura Formations, respectively. The middle member has been named Arroyo Sásabe Formation (Jacques-Ayala, 1991), and it is correlative to the Mural Limestone.

Ransome (1904) defined the sequence of the Bisbee Group in the Mule Mountains, near Bisbee, Arizona. He divided this group into four units: the Glance Conglomerate at the base, the Morita Formation, the Mural Limestone, and the Cintura Formation at the top.

STRATIGRAPHY

CINTURA FORMATION (FORMAL NAME)

Description

The name Cintura Formation is assigned, in a formal manner, to the sequence formed of red to purplish-red mudstone and shale, and minor fine to medium-grained sandstone, exposed on both flanks of the Sierra El Chanate. In the area in which the Cintura Formation crops out, four sections were measured and

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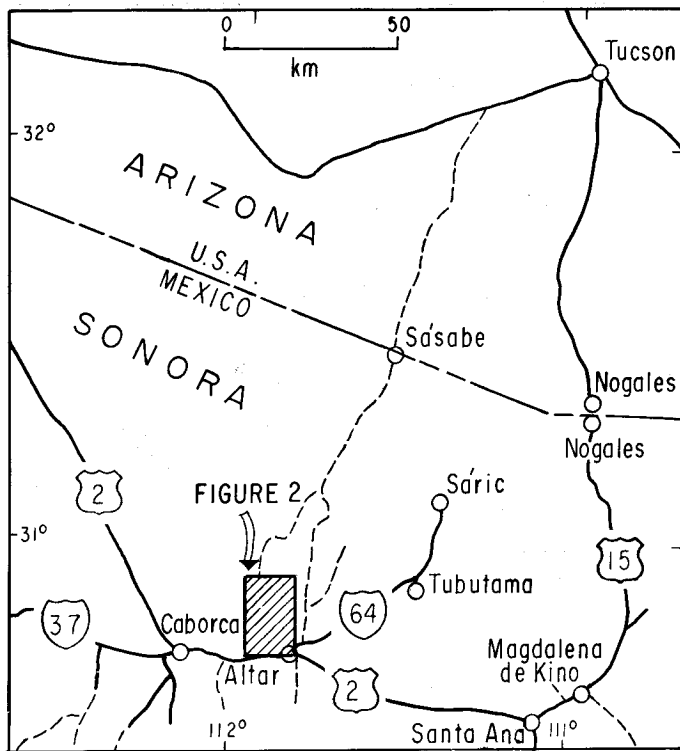


Figure 1.- Map of northwestern Sonora and southern Arizona with the location of the study area.

described: one on the northern flank and three on the southern flank.

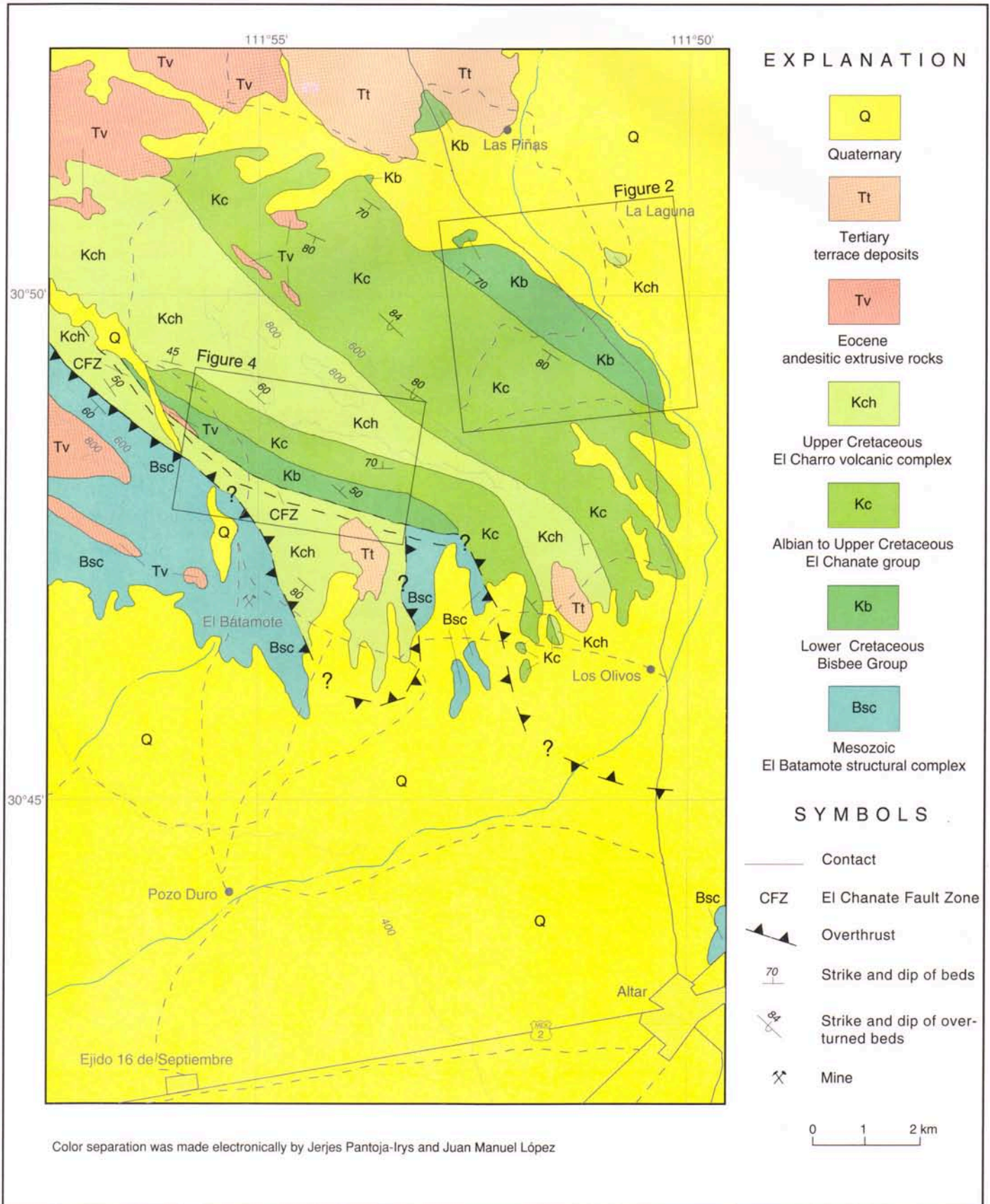
Distribution

The Cintura Formation is exposed north of the Sierra El Chanate as part of the northern limb of a NW trending syncline. In this part of the area, it is 319 m thick. In aerial photographs and satellite images, it shows a well-defined pattern, making good contrast with the Arroyo Sásabe Formation, that underlies it. The upper contact with the Pozo Duro formation can also be traced in aerial photographs, because of the whitish streaks of the quartz-pebble conglomerates that define its base. On the southern limb of the fold, where it forms rolling hills, the Cintura Formation does not show a clear pattern on aerial photographs, except for its upper contact. The three sections measured on the southern limb are 207, 170, and 176 m thick. They are very well exposed, especially along the arroyos.

Description of sections

Section I. This section was measured on the northern side of the Sierra El Chanate (Figure 2). In this area, the topography is nearly flat, with only some elongated hills formed by the conglomerates at the base of the Pozo Duro formation (El Chanate group). The contact between the two units lies on the northern slope of a hill, near the top. The section can be reached through a well-kept dirt road that goes from the town of Altar to Los Chirrones and La Laguna ranches. The starting point of the section is near the top of the highest ledge, located about 500 m south of the road, and the ending point is almost at the road. Cartesian coordinates for this point of the section are: X=418,850 and Y=3'409,750 (DEGETENAL, 1980). Section I is illustrated in Figure 3.

SECTION I		
Unit	Lithology	Thickness (m) Unit Cumul.
1.-	Shale, red, fissile, grades down to a red, fine to medium-grained sandstone in thin beds, which in turn grades into a red to reddish-brown conglomeratic sandstone lens. Sharp contact with...	4 4
2.-	Shale, red, fissile, poorly exposed. Sharp contact with...	14 18
3.-	Sandstone, greenish-brown to red, medium to thin-bedded, medium to fine-grained, with plane-parallel and incipient cross-bedding. The sandstone alternates with red, thick to medium-bedded mudstone. Sharp contact with...	15 33
4.-	Shale, red, fissile, and massive. Contains small calcareous nodules, and has intercalations of red, thin beds of fine-grained, laminated sandstone. Sharp contact with...	22 55
5.-	Sandstone, grayish-brown, in thick beds with plane-parallel lamination and cross-stratification. At the base is a conglomerate consisting of mudstone rip-up clasts. Sharp contact with...	6 61
6.-	Shale, red, fissile, homogeneous, with disseminated calcareous nodules. Sharp contact with...	9 70
7.-	Sandstone, purplish-gray, medium to fine-grained, medium bedded with plane-parallel stratification. Sharp contact with...	4 74
8.-	Shale, red, fissile, and homogeneous, with a few calcareous nodules. Interbeds of red sandstone, 30 to 40 cm thick and fine to medium-grained, are also present. Transitional contact with...	25 99
9.-	Sandstone, purplish-gray, medium-grained, with thin plane-parallel bedding. Poorly exposed. Transitional contact with...	4 103
10.-	Shale, red, fissile, homogeneous, with calcareous nodules and few layers (less than 50 cm thick) of thin purplish-gray, fine to medium-grained sandstone. Some sandstone lenses with a basal conglomerate define channels.	41 144
	Covered.	70 214
11.-	Conglomerate, gray to mottled, 40 cm thick, in sharp contact with purplish-gray, thin-bedded, medium-grained sandstone. Sharp contact with...	1 215
12.-	Shale, red, fissile, and homogeneous, with a few calcareous nodules. Some minor intercalations of red mudstone and fine to medium-grained sandstone in thin beds are also present. Transitional contact with...	13 228
13.-	Sandstone, gray, weathers brownish-gray, medium to fine-grained in plane-parallel thin beds and laminae. A few intercalations of red mudstone are also present. Sharp contact with...	8 236
14.-	Shale, grayish-green, very fissile, massive, and poorly exposed. Sharp contact with...	5 241
15.-	Shale, red, fissile, with thin interbeds of fine-grained sandstone and mudstone. Transitional contact with...	18 259
16.-	Sandstone, purplish to brownish-gray, thin-bedded, fine to medium-grained, apparently bioturbated. Toward the bottom, bedding is thicker, and includes rip-up clasts. The base of this unit is formed by a conglomeratic lens 50 cm thick, consisting of metamorphic(?) and sedimentary fragments less than 5 cm in diameter. Sharp contact with...	6 265
17.-	Shale, red, fissile, with lenticular intercalations less than 1 m thick of brownish to purplish-gray, medium-grained sandstone. Sandstone beds have a thin pebbly conglomeratic base. Transitional contact with...	39 304
18.-	Sandstone, purplish-gray, thin-bedded, and	



SIMPLIFIED GEOLOGIC MAP OF THE SIERRA EL CHANATE

- medium-grained. Poorly exposed. Sharp contact with... 7 311
 - 19.- Shale and mudstone, red, with a layer of calcareous nodules at the top. Transitional contact with... 2 313
 - 20.- Sandstone, greenish-gray to brownish-green, thin-bedded, fine to medium-grain. Sharp contact with... 6 319
- Arroyo Sásabe Formation.

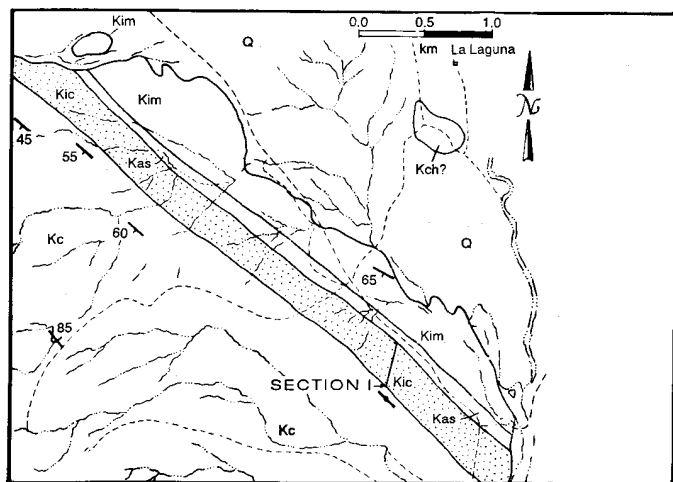


Figure 2.- Detailed geologic map of the northeastern corner of the Sierra El Chanate area and location of the section I. The map is drawn from a 1:20,000 scale aerial photograph. Symbols are the same as in Plate 1, except for: Kim—Morita Formation; Kas—Arroyo Sásabe Formation; Kic (stippled)—Cintura Formation.

Section II. - This section is located on the southwestern side of the Sierra El Chanate (Figure 4). It can be reached by the road that goes from the Rancho Pozo Duro, northward, parallel to the Arroyo El Charro, and then westward along the low reaches of the sierra. Past a fence, the road goes across three arroyos. Section II was measured along the third arroyo. Cartesian coordinates for the beginning of the section are X=411,180 and Y=3'409,150. This section is shown in Figure 5.

SECTION II

Unit	Lithology	Thickness (m)	Unit	Cumul.
1.-	Shale, red to purple, homogeneous, and massive, but foliated, is intercalated with red siltstone, which includes gray medium to coarse-grained, locally conglomeratic, sandstone lenses, several meters thick.	17	17	17
Covered.		19	36	36
2.-	Sandstone, purplish-gray, medium to coarse-grained, it has plane-parallel lamination, and locally thin veneers of mud-chip pebbles. Minor intercalations of red, thin siltstone. Unit is tabular. Even contact with...	7	43	43
3.-	Shale, silty, light-red, foliated, 1 m thick, grades downward into a dark-red, massive, locally sandy mudstone, which has calcareous nodules up to 25 cm in diameter, and some mud-chip conglomerate. Fault contact with...	10	53	53
4.-	Sandstone, grayish-green, thick-bedded, graded bedding ranging from coarse to fine. Fractures filled by calcite.	2	55	55
5.-	Mudstone, dark-red, massively-bedded, locally with abundant very small calcareous nodules, with			

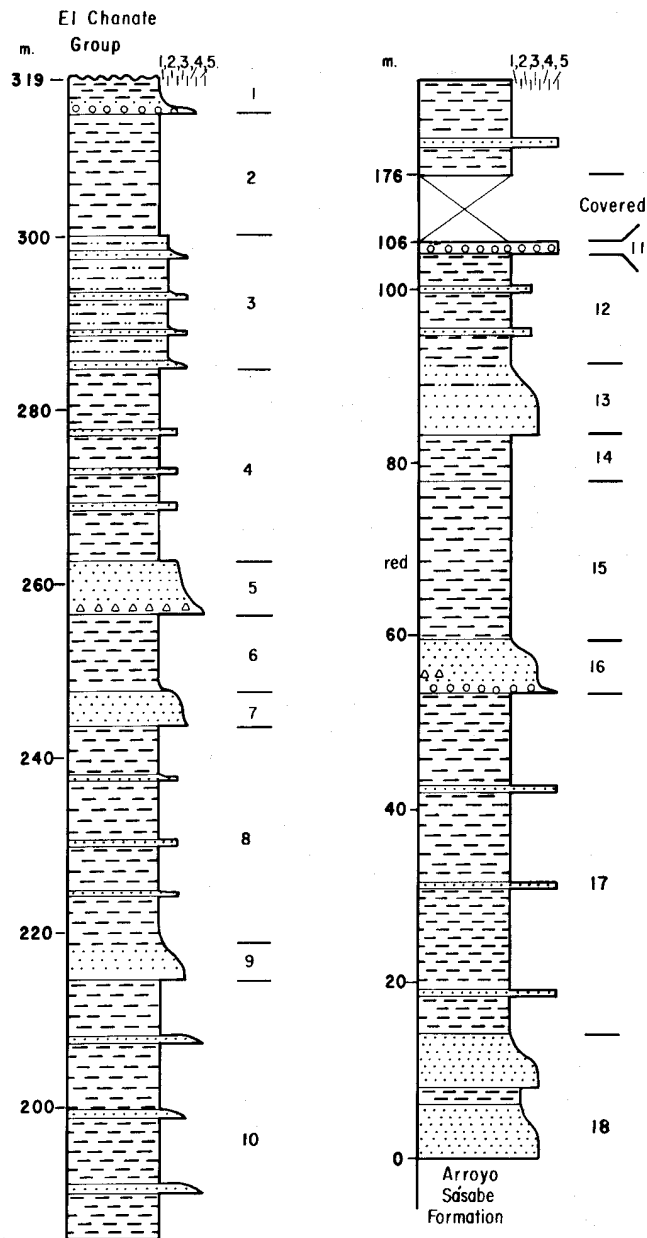


Figure 3.- Stratigraphic column of the section I. Location shown in Figure 2. Numbers to the right correspond to the units described in the text. Numbers on top-right of the column indicate grain size: 1—shale; 2—fine sand; 3—medium sand; 4—coarse sand; 5—pebbles.

intercalations of dark-red siltstone. It also has some flame structures, mud-chip pebble layers and is bioturbated.	17	72
Covered.	3	75
6.- Sandstone, purplish-gray, medium-grained, stratification is laminated to thinly-bedded, and has some mud-chip pebbles. Erosional contact with...	1	76
7.- Mudstone, dark-red, massively-bedded, silty, has thin layers of mud-chip pebbles. Poorly exposed. Covered contact with...	6	82
8.- Sandstone, purplish-gray, medium-grained, and medium to thin-bedded, it has layers of very angular to irregular mud-chip pebbles. Sharp contact with...	3	85
9.- Mudstone, dark-red, massively-bedded and silty, contains small calcareous to shaly nodules, with malachite. Unit is foliated. Sharp contact with...	4	89
10.- Sandstone, gray, medium-grained, highly fractured.		

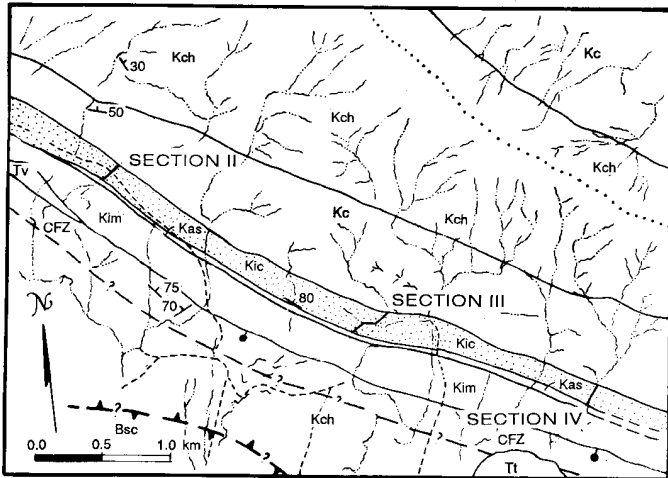


Figure 4.- Detailed geologic map of the south-central part of the Sierra El Chanate area and location of the sections II, III and IV. Map drawn from a 1:20,000 scale aerial photograph. The symbols are the same as in Figure 2.

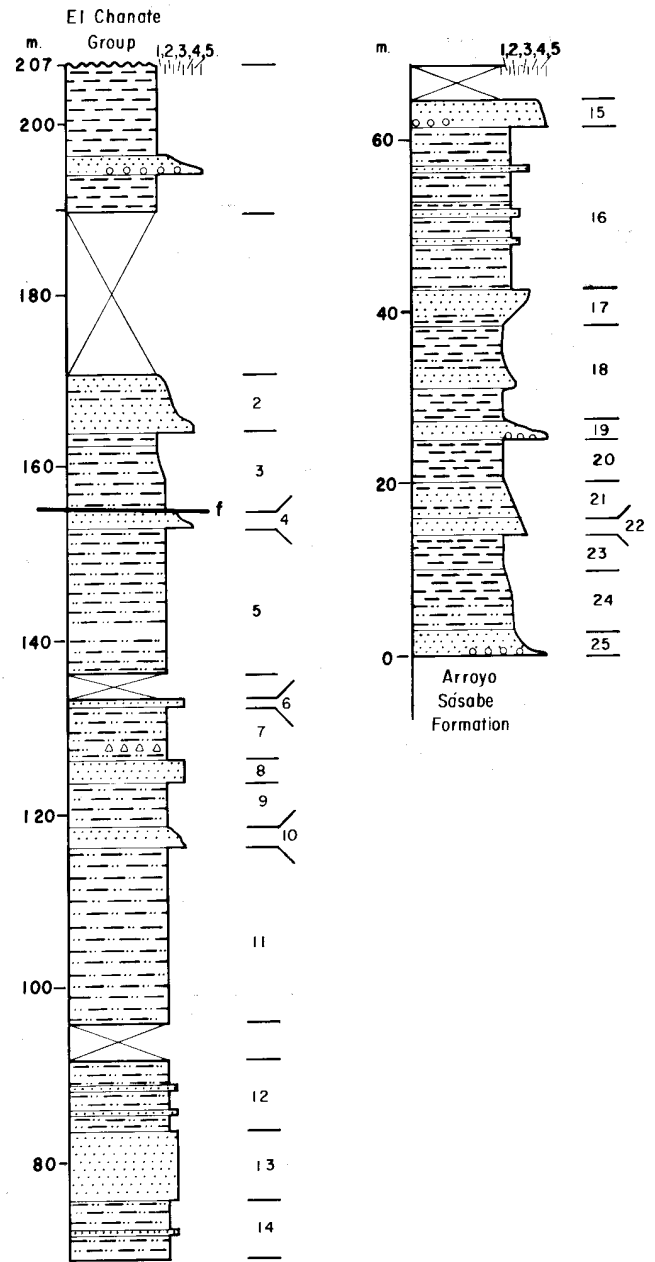


Figure 5.- Stratigraphic column of the section II. Location shown in Figure 4. Numbers to the right correspond to the units described in the text. Numbers are the same as in Figure 3.

- | | | |
|--|----|-----|
| Sharp contact with... | 2 | 91 |
| 11.- Mudstone, same as in unit 9. | 21 | 112 |
| Covered. | 4 | 116 |
| 12.- Mudstone, purplish-red, with small calcareous nodules. There are some thin intercalations of purplish-red, fine-grained sandstone. Unit is locally foliated, and also highly-fractured, but fracturing diminishes downward. Sharp irregular contact with... | 8 | 124 |
| 13.- Sandstone, red, fine-grained, thick-bedded, has intercalations of red mudstone with very small calcareous nodules. Color changes locally to red because of a small andesitic dike which cuts the unit. Locally folded and fractured. Sharp irregular contact with... | 8 | 132 |
| 14.- Mudstone, red and bioturbated, it has calcareous nodules, and is intercalated with gray to green, medium-bedded, medium to fine-grained sandstone. Few thin interbeds of poorly exposed red shale are also present. | 7 | 139 |
| Covered. | 4 | 143 |
| 15.- Sandstone, purple to gray and green, medium to coarse-grained, medium-bedded, and faintly-laminated, it has some cross bedding, and in places is conglomeratic. Sharp irregular contact with... | 3 | 146 |
| 16.- Mudstone, red, thick-bedded, intercalated with red, thick-bedded shale. Unit has abundant calcareous nodules. Covered contact with... | 19 | 165 |
| 17.- Sandstone, purple, medium to thin-bedded, medium-grained, with mud-chip pebbles. In the middle third, the sandstone is finer, bedding is thinner to laminated, and it is intercalated with mudstone. The lower third includes shale interbeds with some sandstone intercalations. Sharp irregular contact with... | 4 | 169 |
| 18.- Shale, red to purple, thick-bedded, with intercalated mudstone and fine sandstone in medium to thick beds. The shale contains large calcareous nodules. Transitional contact with... | 11 | 180 |
| 19.- Sandstone, thick-bedded, internally laminated, medium to fine-grained with a thin conglomerate at the base. Sharp irregular contact with... | 2 | 182 |
| 20.- Shale and mudstone, red, homogeneous, slightly-bioturbated, with some calcareous nodules, disseminated and along bedding planes. Transitional contact with... | 5 | 187 |

- | | | |
|--|---|-----|
| 21.- Sandstone, red, fine-grained, medium-thick beds, alternates with thin beds of red shale. The base is formed by a 1 m thick shale. Transitional contact with... | 4 | 191 |
| 22.- Sandstone, gray to green, medium-bedded with thin internal plane and cross stratification, medium grained, it has few thin intercalations of conglomerate made of fragments less than 2 cm in diameter. Sharp contact with... | 2 | 193 |
| 23.- Shale, red, thin-bedded, foliated, is intercalated with purple, medium-bedded, internally with plane-parallel laminations, medium to fine-grained sandstone. Sharp irregular contact with... | 4 | 197 |
| 24.- Shale, red, massive, homogeneous, and foliated, grades down into purple, laminated mudstone and thin-bedded shale. Transitional contact with... | 7 | 204 |
| 25.- Sandstone, greenish-gray, medium-bedded, | | |

medium-grained, with lenses of pebble conglomerate. Sharp irregular contact with... 3 207
 Arroyo Sásabe Formation.

Section III. This section was measured along a gully located on the southern rim of the Sierra El Chanate, about 2.8 km north of the El Batamote mine (Plate 1). The end point of the section can be reached by the road that goes from Rancho Pozo Duro to the El Batamote mine and northwest (Figure 4), always taking the road to the right. The coordinates of the initial point are X=413,250 and Y=3'408,100. This point is located on the top of the hill, where the arroyo makes a wide U turn open to the west. Figure 6 is a panoramic view of this section as observed from the right margin toward the NE. Section III is illustrated in Figure 7.



Figure 6.- View toward the northeast of the southern central part of the Sierra El Chanate. In the foreground is the Arroyo Sásabe Formation; in the central part, with a darker tone of gray, is the Cintura Formation overlain by the Cretaceous Pozo Duro Formation (El Chanate Group) in light gray. In the background, forming the axis of the sierra, is the Cretaceous El Charro volcanic complex.

SECTION III

Unit	Lithology	Thickness (m)	Unit	Cumul.
1.-	Mudstone, alternating purple to red. The purple mudstone is very thick-bedded with internal, very-thin parallel to irregular bedding, that is locally bioturbated. The red mudstone is massive, in thick beds, and has no internal structures. Partially covered by talus.	70	70	
	Covered.	24	94	
2.-	Sandstone, gray to purple, thin-bedded, fine-grained; alternates with purple, thin-bedded mudstone and lenses of mud-chip conglomerate. Contains few calcareous nodules. Transitional contact with...	6	100	
3.-	Sandstone, green, very fine-grained, occurs in thin beds and has abundant dissolution cavities after calcite(?) nodules. Transitional contact with...	2	102	
4.-	Sandstone, gray, coarse to medium-grained, thin-bedded, with intercalations of mud-chip conglomerate. The chips are composed of micstone and green mudstone and very fine sandstone. The base of this unit consists of a mud-chip conglomerate, forming a fining upward cycle with units 2 and 3. Sharp irregular contact with...	5	107	
5.-	Sandstone, purplish-gray, medium-grained with some rip-up clasts, and medium-bedded with thin planar			

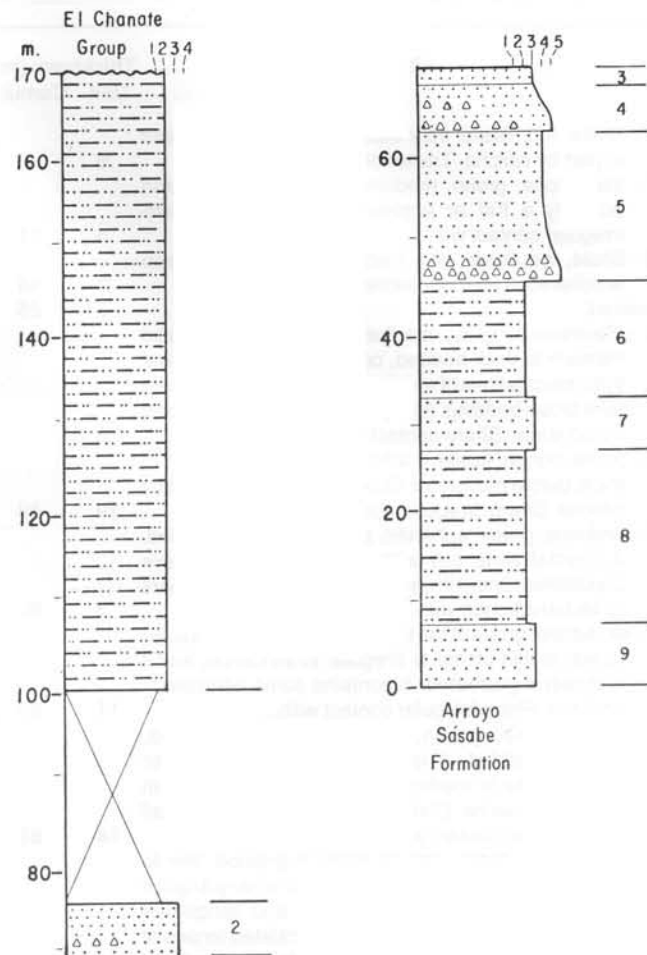


Figure 7.- Stratigraphic column of the section III. Numbers to the right indicate the units described in the text. For location see Figure 4. Numbers are the same as in Figure 3.

	and crossed stratification and lamination. It grades downward to a 3 m thick clay-pebble conglomerate. Sharp irregular contact with...	17	124
6.-	Mudstone, purple, homogeneous, with bioturbation structures. Transitional contact with...	13	137
7.-	Sandstone, gray, and fine-grained, occurs in thick beds with plane-parallel and crossed stratification and lamination. This unit wedges into red mudstone. Sharp irregular contact with...	6	143
8.-	Mudstone, gray to purple, thin-bedded, with intercalations of strongly bioturbated beds. Covered contact with...	20	163
9.-	Sandstone, gray to purple, fine-grained, very thin-bedded to laminated, contains intercalated lenses of coarse sandstone and purple mud-chip conglomerates. Cross-bedding is common. Sharp, erosional contact with...	7	170
	Arroyo Sásabe Formation.		

Section IV. This section (Figure 8) was measured along a gully on the southern rim of the Sierra El Chanate (Figure 5). The end point can be reached by the road that goes southeastward from the El Batamote mine for about 2.8 km, then follow a barely visible road that goes to the north (Figure 2). This road begins before going through the arroyo, past of which is a locked gate. The junction of the two roads has coordinates X=415,300 and Y=3,405,020. The coordinates of the initial point of the section are X=414,900 and Y=3,407,650.

SECTION IV

Unit	Lithology	Thickness (m)	
		Unit	Cumul.
1.-	Shale, red, fissile, very friable, altered and covered in part by caliche. Transitional contact with...	6	6
2.-	Sandstone, green, medium-grained, massive, and possibly a tuff or volcanoclastic deposit? Sharp irregular contact with...	5	11
3.-	Shale, red, fissile, very friable, and altered. Outcrop is covered in part by caliche.	7	18
Covered.		7	25
4.-	Sandstone, gray, medium to fine-grained, and medium to thick-bedded, contains rip-up clasts and thin intercalations of red, fine-grained sandstone with faint cross-bedding. Also present is a 1.5 m thick bed of red shale. Sharp contact with...	5	30
5.-	Shale, purple, fissile, grading near the base to a 1 m thick, purple mudstone. Outcrop is in part covered by caliche. Sharp, irregular contact with...	19	49
6.-	Andesite, green, aphanitic, and apparently stratified. A crystal-vitric tuff with the base being more crystalline? Sharp irregular contact (by color appears to be transitional) with...	3	52
7.-	Mudstone, green at the top, changes to purple, locally fissile, in thin planar to irregular stratification, and it is locally bioturbated. It contains some calcareous nodules. Sharp irregular contact with...	11	63
8.-	Sandstone, green, fine to medium-grained, medium-bedded, it is intercalated with green to purple shale in medium to thick beds. Covered in places by caliche. Unit is fractured and cut by small faults. Sharp contact with...	18	81
9.-	Sandstone, green, fine to medium-grained, thin to medium-bedded, with thin plane-parallel stratification, as well as planar and tangential cross-stratification. It contains intercalated lenses of rip-up clast conglomerate. The clasts are of red and green mudstone and gray micstone. Transitional(?) contact with...	12	93
10.-	Sandstone, green, medium-bedded, fine-grained to siltstone. Sharp, irregular contact with...	11	104
11.-	Sandstone, green, medium-bedded, medium to fine-grained, interbedded with green, thin-bedded shale. Sharp contact with...	9	113
12.-	Sandstone, gray, coarse to granular (up to 5 mm in diameter), thin-bedded, and micstone clasts, cemented by calcite. Sharp irregular contact with...	1	114
13.-	Sandstone, green, thin-bedded, and intercalated with green, thin-bedded shale. Poorly exposed. Covered contact with...	3	117
14.-	Sandstone, green, fine-grained, homogeneous, hard, and medium to thick-bedded. Transitional contact with...	4	121
15.-	Siltstone to mudstone, light green, hard, homogeneous, medium to thick-bedded, it has calcareous nodules which dissolve leaving cavities. Covered.	13	134
		2	136
16.-	Andesite, green, and porphyritic, has small phenocrysts of plagioclase and amphibole(?) Covered.	2	138
		8	146
17.-	Sandstone, green, homogeneous, medium-bedded, and poorly exposed. Covered contact with...	4	150
18.-	Shale, purple, fissile, poorly exposed. Grades into...	10	160
19.-	Sandstone, purple, fine-grained, thin-bedded, with few intercalations of shale. Toward the top, the sandstone has a mottled appearance, probably because of bioturbation. Transitional contact with...	10	170
	Sandstone, gray, weathers blackish-green, medium-grained, thick-bedded, with few thin beds. Sharp contact with...	6	176
Arroyo Sásabe Formation.			

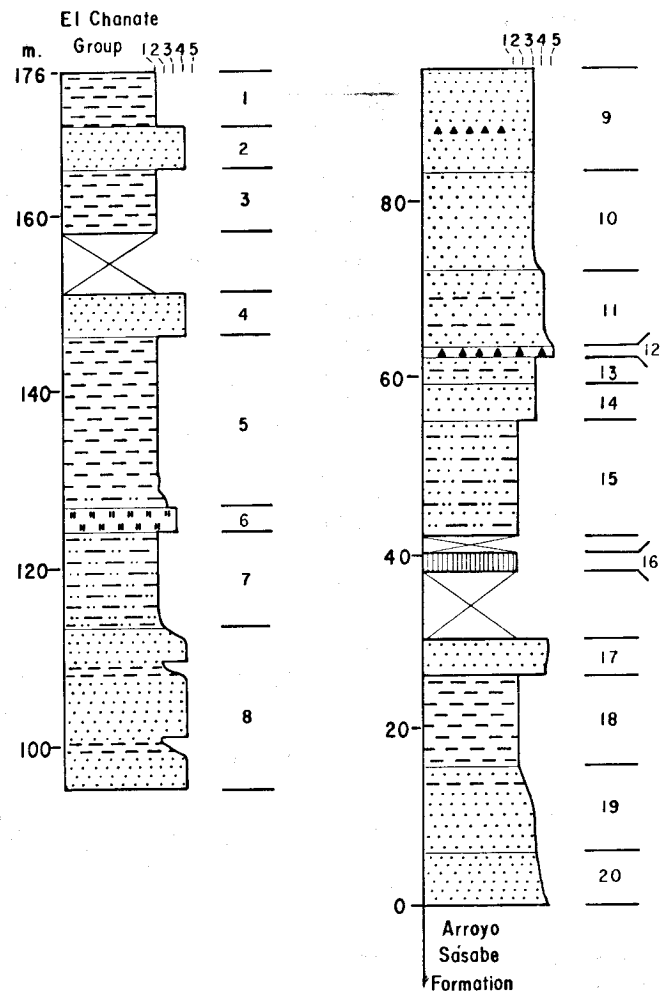


Figure 8.- Stratigraphic column of the section IV. Numbers to the right indicate the units described in the text. For location see Figure 4. Numbers are the same as in Figure 3.

Stratigraphic relationships

The basal contact of the Cintura Formation is conformable, from abrupt to transitional, with the Arroyo Sásabe Formation (Jacques-Ayala, 1991). Locally, the green sandstone and shale that occur near the top of the Arroyo Sásabe are also found near the base of the Cintura, and so the contact is placed where the color changes from green to red.

The upper contact varies from conformable to a very shallow angular unconformity with the Pozo Duro formation of the El Chanate group (Jacques-Ayala *et al.*, 1990b). The Pozo Duro is characterized by the presence of quartz-pebble conglomerate lenses in a red mudstone and shale. Where the conglomerate is not present, the contact is difficult to define.

Age and correlation

No fossils have been collected from the Cintura Formation in the Sierra El Chanate area. The underlying Arroyo Sásabe Formation is assigned a late Aptian age, based on the presence of *Quadratortonia* cf. *Q. mearnsi* (Stoyanow), *Pterotrionia* sp., *Macraster* cf. *M. dartoni* (Cooke) (Jacques-Ayala *et al.*, 1990a). The uppermost part of the Anita formation (formerly member ECN-5 of Jacques-Ayala and Potter, 1987) of the El Chanate group contains *Crassatella* (*Pachythaerus*) sp., *Tellina* cf. *T.*

bigotina d'Orbigny and *Rissoa* cf. *R. dupiniana* d'Orbigny which indicate an Albian age for this unit (Jacques-Ayala *et al.*, 1990a). Therefore, the Cintura Formation can be assigned to the early-middle Albian. Araujo-Mendieta and Estavillo-González (1987, p. 21) assign a middle Albian age to the Cintura in the Sahuaripa area. Rocks similar to the Cintura Formation have been reported from nearby areas. Willard (1988) described a sequence of red mudstone and sandstone in the Puerto El Alamo, 10 km west of the El Chanate. This sequence is, at present, the westernmost exposure of Bisbee-like rocks that have been described. Harrar (1989) also reports the continuation of these units eastward into the Sierra El Batamote, where they are thrust by a foliated sequence. Jacques-Ayala and others (1990b) report the presence of the Bisbee Group in the northwestern part of the Cerros El Amol, 5 km east of Oquitoa, and Navarro-Fuentes (1989) reports more than 500 m of Cintura Formation in the Santa Ana area. In this area, the Cintura was previously reported, but not identified as such, by Flores (1929) and Salas-Pizá (1968). On the other hand, González-León and Jacques-Ayala (1990) described the Cintura Formation in the Cerro de Oro area, which is more than 290 m thick.

Regional correlation can be made with the Cintura from northeast Sonora and southeast Arizona (Ransome, 1904; Taliaferro, 1933; Drewes, 1971; Hayes, 1970; González-León, 1978; Rangin, 1982; Archibald, 1987; Rodríguez-Castañeda, 1988). In central and east-central Sonora, time equivalent units have been described in Lampazos (González-León, 1988; Scott and González-León, 1990), where it consists mainly of marine limestone and shale.

DISCUSSION

Paleogeographically, the Cintura Formation was deposited in a tidal flat to alluvial plain, with some fluvial as well as marine influence. The presence of the stromatolite *Columnacollenia* Korolyuk (1968) (Jacques-Ayala and Potter, 1987) supports the tidal flat environment. This unit represents the regressive phase of the Bisbee Group, which had its maximum sea advance during Mural and/or Arroyo Sásabe times (Warzeski, 1987). The regressive nature of the Cintura is not clearly observable in the Sierra El Chanate, for there is no coarsening-up of the sequence, and the amount of conglomerate, respect to mudstone, is negligible. Furthermore, the sequence is characterized mostly by fining-upward cycles, and very few coarsening-up. Sections II and III appear to represent a fining-up sequence. An explanation to this could be the absence of the coarser fraction because of erosion.

Tectonically, the Bisbee Group in this part of Mexico represents a period of slow regional subsidence, because depositional environments did not shift abruptly from one unit into the other. In the Sierra El Chanate, sedimentation conditions—related to sea level—remained highly stable. The Morita and Cintura Formations were deposited in tidal to alluvial flood plains, whereas the Arroyo Sásabe was part of a lagoon. It was at the end of the Cintura time that tectonic instability began, uplifting and folding the Bisbee. The onset of the Sevier orogeny is recorded by the quartz-pebble conglomerates in the basal unit of the El Chanate group (Jacques-Ayala *et al.*, 1990b). Near section I, these conglomerates include angular cobbles and blocks of red to gray sandstone derived from the underlying Cintura Formation.

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