

# Some Jurassic Ammonites From Central Saudi Arabia

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 643-D

*Prepared in cooperation with the Saudi Arabia  
Ministry of Petroleum and Mineral Resources  
and the U.S. National Museum, under the  
sponsorship of the Kingdom of Saudi Arabia  
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By RALPH W. IMLAY

CONTRIBUTIONS TO PALEONTOLOGY

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*Descriptions and illustrations of some  
stratigraphically useful ammonites from  
Saudi Arabia*

**UNITED STATES DEPARTMENT OF THE INTERIOR**

**WALTER J. HICKEL, *Secretary***

**GEOLOGICAL SURVEY**

**William T. Pecora, *Director***

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## CONTRIBUTIONS TO PALEONTOLOGY

### SOME JURASSIC AMMONITES FROM CENTRAL SAUDI ARABIA

By RALPH W. IMLAY

#### ABSTRACT

Jurassic ammonites collected stratigraphically in central Saudi Arabia show that the ammonite sequence and the ages of the formations as determined by Arkell in 1952 are essentially correct and need modification only for parts of the Dhurma Formation. In particular, the middle Bajocian age of the lower part of the Dhurma Formation is extended upward nearly to the *Ermoceras* beds by an occurrence of *Dorsetensia* just below the Dhibi Member. A late Bajocian age for the upper part of the *Ermoceras* beds is proved by the association of *Spiroceras bifurcatum* (Quenstedt) with *Ermoceras* and *Thamboceras* throughout 5.5 meters of beds just above the Dhibi Member.

The Bathonian age of most of the middle part of the Dhurma Formation above the *Ermoceras* beds is upheld by the ammonites present. An early Bathonian age for the lower part of the *Thambites* beds is indicated by stratigraphic position. A middle Bathonian age for the upper part of those beds is shown by the presence of *Clydoniceras*, provided that the genus has the same range as in Europe. Also, rare occurrences of *Thambites* as high as the *Micromphalites* beds show definitely that *Thambites* ranges up into the middle Bathonian. A middle Bathonian age for the overlying *Tulites* and *Micromphalites* beds is unquestioned. A late Bathonian age for the *Dhurmaites* beds at the top of the middle part of the Dhurma Formation is favored stratigraphically but is not proved faunally. Nonetheless, the presence of a single specimen of *Dhurmaites* from near the base of the *Thambites* beds shows that the genus existed early in Bathonian time and that the main *Dhurmaites* beds are logically part of the Bathonian succession.

A Callovian age for most of the upper part of the Dhurma Formation is proved by the presence of the middle Callovian ammonites *Pachyceras* and *Ermoceras* near the base of the upper part and by the identity of several species with ammonites in the basal part of the overlying Tuwayq Mountain Limestone. The early Callovian is either represented by the lower 11 meters of the upper Dhurma Formation, or by the underlying *Dhurmaites* beds, or by a disconformity.

#### INTRODUCTION

This study of some Jurassic ammonites from central Saudi Arabia is a natural extension of the geologic mapping project of the Arabian Peninsula carried out by the Arabian-American Oil Co. (Aramco) and the U.S. Geological Survey under the joint sponsorship of the Kingdom of Saudi Arabia, Ministry of Petroleum

and Mineral Resources, and the U.S. Department of State. It is based mainly on collections made by geologists of the Arabian-American Oil Co. and the U.S. National Museum since 1952, when W. J. Arkell described all the available Jurassic ammonite collections from central Saudi Arabia and evaluated their age significance in terms of the standard European stages (Arkell, 1952). A new evaluation of the age significance of the ammonites at this time is opportune because other paleontologists are now describing the associated echinoids and pelecypods, which, although much more abundant than the ammonites in Saudi Arabia, are generally less useful for regional correlations and age determinations. Only those ammonites that were not available to W. J. Arkell or that add new biologic or stratigraphic data are described herein.

Much of the data presented herein concerning the age of the Dhurma Formation is based on fossil collections made by the Aramco geologists between 1952 and 1962 and by geologists of the U.S. National Museum in 1962. Many thanks are due to the Aramco geologists, R. W. Powers and S. D. Bowers, for the privilege of studying their ammonite collections, for furnishing locality data, and for preparing a locality map of the fossil collections made in 1962 (fig. 1). The excellent preservation of some Arabian Jurassic mollusks and echinoids, submitted to me by the Aramco geologists in 1960, stimulated the U.S. National Museum specialists Erle Kauffman and Porter Kier to go to Saudi Arabia in 1962; thanks are also due to these specialists for furnishing data concerning the fossils collected by them.

#### BIOLOGICAL RELATIONSHIPS

The systematics of most of the Jurassic Toarcian to Callovian ammonites of central Saudi Arabia were discussed in considerable detail by Arkell in 1952 (p. 260, 261, 266, 272, 273, 278, 279, 282, 286-289, 291, 302-306) and were modified slightly by him in 1957 (Arkell and others, p. L258, L296). Some of his assignments were later modified by Westermann (1965, p. 868-871) who

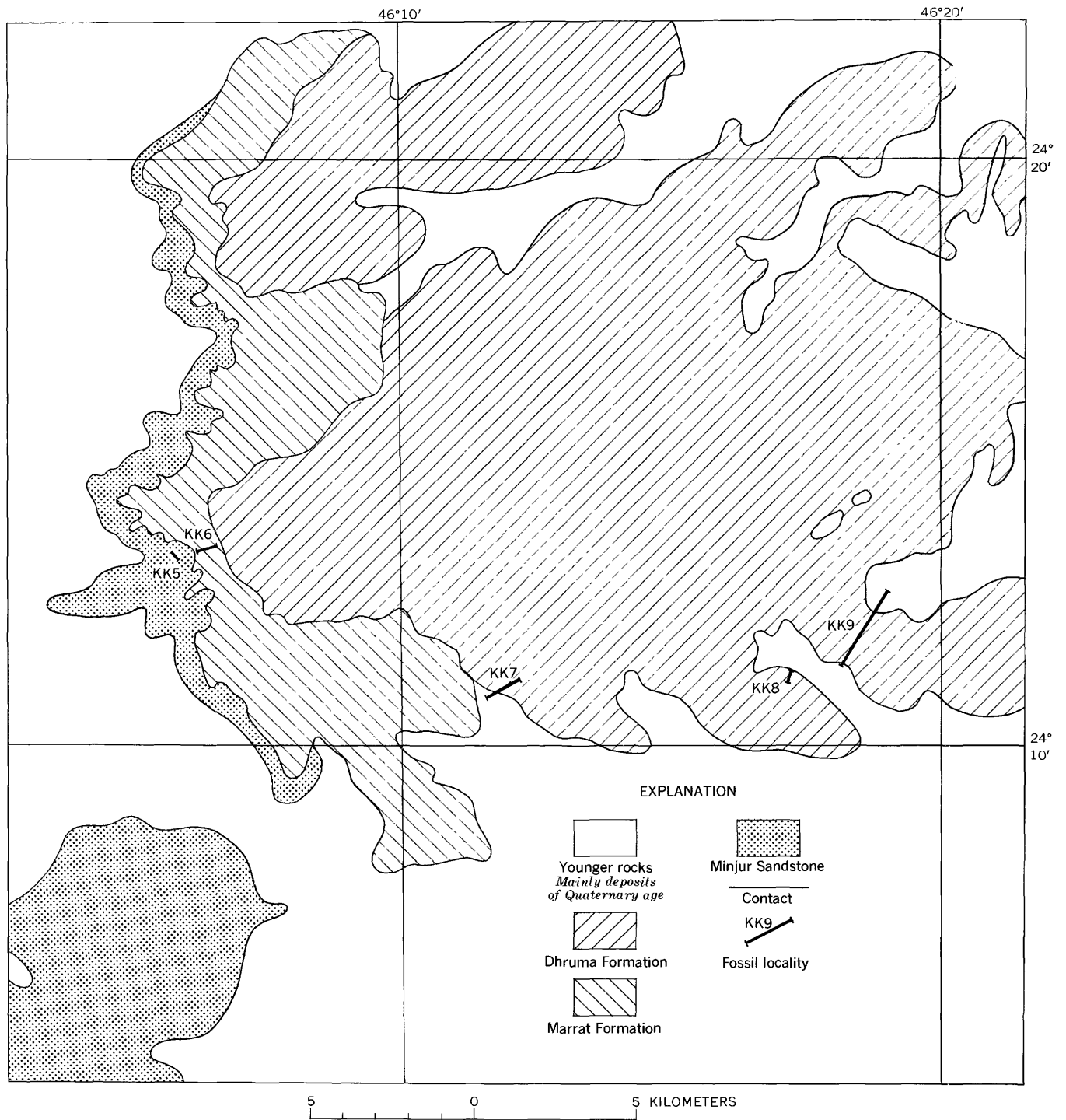


FIGURE 1.—Generalized geologic map of part of the Northern Tuwayq quadrangle, Saudi Arabia, showing the Jurassic fossil localities where collections were made by P. M. Kier, E. G. Kauffman, R. W. Powers, H. A. McClure, and C. D. Redmond in 1962. Prepared by R. W. Powers and S. D. Bowers, Arabian-American Oil Co.



assigned *Ermoceras* to the Thamboceratidae because of the characteristics of its sutural pattern and the presence of a ventral groove. For the same reasons, specimens that were identified with *Stephanoceras* and *Teloceras* by Arkell (1952, p. 270, 271) were assigned to *Ermoceras* by Westermann (1965, p. 871, pl. 101, figs. 4-6). Furthermore, worn specimens of *Normannites*? sp. from Saudi Arabia that were described by Arkell (1952, p. 277) as *Normannites* cf. *N. orbigny* Buckman (see pl. 1, figs. 9-12) were considered to be "probably stephanoceratid," by Westermann (1965, p. 871). In fairness to Arkell, his discussion of *Ermoceras* (Arkell, 1952, p. 272) shows that he did not consider the presence of a ventral growth to be a family characteristic; he was highly uncertain about the family assignment of *Ermoceras*; and he believed that the Thamboceratidae arose from *Ermoceras* (Arkell, 1952, p. 305, 306; Arkell and others, 1957, p. L290).

The biological composition of the ammonite faunas as described by Arkell (1952) and supplemented by the present study is summarized in table 1.

#### STRATIGRAPHIC COMMENTS

The Jurassic formations of central Saudi Arabia have been described briefly by Bramkamp and Steineke (in Arkell 1952, p. 245-249), by Steineke, Bramkamp, and Sander (1958, p. 1303-1308) and in detail by Powers, Ramirez, Redmond, and Elberg (1966, p. D39-D66). No lithologic or detailed stratigraphic data are repeated herein because the latest two papers are readily available and because the present paper deals primarily with the faunal and age relationships of the Dhruma Formation and the adjoining formations, as based on ammonites (figs. 2, 3).

#### FAUNAL SEQUENCES AND CORRELATIONS

The ammonite succession and the age determinations that were made by Arkell (1952, p. 293-299) for the Jurassic formations in central Saudi Arabia have been upheld very well by subsequent studies (fig. 3). Still unquestioned are his assignments of the Marrat Formation to the lower and middle Toarcian and of the lower marly beds of the Tuwayq Mountain Limestone to the middle Callovian. His assignment of the Dhruma Formation to the middle and upper Bajocian and the Bathonian is still valid except for the upper part of the formation, which is now dated as middle Callovian on the basis of ammonites collected in 1962. Arkell had no evidence based on ammonites, and there still is none, for the presence of beds of late Toarcian, Aalenian, and early Bajocian ages. He likewise found no ammonites of early Callovian age, but did not exclude the upper part of the Dhruma Formation from being of that age.

An unconformity of possible late Toarcian to early Bajocian duration between the Marrat and Dhruma Formations is suggested by the absence of ammonites of those ages (Arkell, 1952, p. 295-303) and by the fact that there are only about 28 meters of beds between the ammonite faunules of middle Toarcian and middle Bajocian ages (Bramkamp and Steineke, 1952, p. 250, 265, 295). This suggestion is strengthened by the presence in some places of a sharp lithologic break between the formations and in other places by unconformable overlap of the Dhruma Formation across the Marrat and several older formations (Powers and others, 1966, p. D45).

The middle Bajocian to middle Callovian ages now assigned to the Dhruma Formation are based not only on the ammonites described by Arkell (1952, p. 268-292) but on other ammonites found later (table 2).

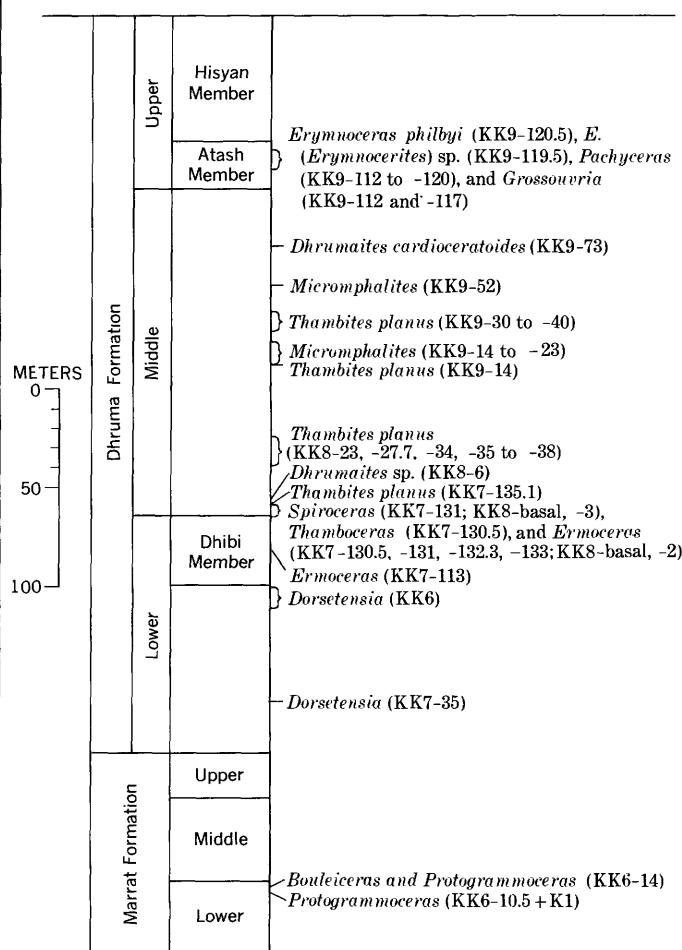


FIGURE 2.—Stratigraphic distribution of ammonites collected by P. M. Kier and E. G. Kauffman, U.S. National Museum, and R. W. Powers, H. A. McClure, and C. D. Redmond, Arabian-American Oil Co., in 1962 in central Saudi Arabia. Field locality numbers are given in parentheses. (See fig. 1 and table 3 for location and description.)

TABLE 1.—*Ammonite genera and subgenera of Bajocian to Callovian ages in central Saudi Arabia, showing biological relationships and relative numbers available for this and Arkell's (1952) studies*

Family	Subfamily	Genus and subgenus	Number of specimens available to Arkell (1952)	Additional specimens available for this report
Lytoceratidae	Lytoceratinae	<i>Lytoceras?</i>		1
Spiroceratidae		<i>Spiroceras</i>		5
Hildoceratidae	Bouleiceratinae	<i>Bouleiceras</i>	66?	1
	Hildoceratinae	<i>Hildaites</i>	19	
	Harpoceratinae	<i>Protogrammoceras</i>	27	3
?Hammatoceratidae	?Phymatoceratinae	<i>Nejdia</i>	24	4
Sonninidae		<i>Dorsetensia</i>	38	2
Stephanoceratidae		<i>Stephanoceras?</i>	4	
		<i>Teloceras?</i>	2	
		<i>Normannites?</i>	2	
Thamboceratidae		<i>Thamboceras</i>	3	1
		<i>Thambites</i>	25?	34
		<i>Ermoceras</i>	77	10
Clydoniceratidae		<i>Clydoniceras</i>	5	
		<i>Micromphalites</i>	24	18
		( <i>Clydomphalites</i> )	23	1
		<i>Dhrumaites</i>	4	3
Tulitidae		<i>Tulites</i>	13?	1
Oppelidae		<i>Strungia</i>	1	
Pachyceratidae		<i>Erymnoceras</i>	8?	8
		( <i>Pachyerymnoceras</i> )	1	2
		( <i>Erymnocerites</i> )		1
		<i>Pachyceras</i>	1	2
		<i>Rollierites</i>		1
Perisphinctidae	Pseudoperisphinctinae	<i>Grossowria</i>		2

In particular, studies of the ammonites of the KK series, as listed in figure 2, show that the sequence of ammonite faunas, and hence the ages as determined by Arkell (1952, p. 293), should be modified slightly as shown in figure 3. Thus, *Dorsetensia* ranges as high as near the base of the Dhibi Member (loc. KK6). *Ermoceras* ranges through the Dhibi Member into the lower 5.5 meters of the middle Dhruma Formation and is associated in those 5.5 meters with *Thamboceras* and *Spiroceras*. *Thambites* has a range of nearly 90 meters, from 6.1 meters above the Dhibi Member (loc. KK7-135.1) into the middle of beds characterized by *Micromphalites* (loc. KK9-30 to -40). *Dhrumaites*, although most common near the top of the middle Dhruma Formation, occurs also only 8.5 meters above the Dhibi Member (pl. 3, figs. 6, 7). Lastly, *Erymnoceras* and *Pachyceras*, which Arkell (1952, p. 289-292) records only from the basal marly beds of the Tuwayq Mountain Limestone, are now recorded from much lower beds, in the Atash Member of the upper Dhruma Formation.

A middle Bajocian age for the Dhruma Formation below the Dhibi Member is based on the presence of *Dorsetensia* (fig. 2), which in western Europe, as discussed by Arkell (1952, p. 269, 295), occurs only in the zones of *Otoites sauzei* and *Stephanoceras humphriesianum*. More precise correlation of the *Dorsetensia*-bearing beds in Saudi Arabia with a particular European zone cannot be made, however, because of the lack of associated ammonite genera that might be stratigraphically more restricted than *Dorsetensia*. As those

beds in Saudi Arabia grade upward into beds containing late Bajocian ammonites, they are probably equivalent at least to the *Stephanoceras humphriesianum* zone.

A late Bajocian age for the *Ermoceras* beds in Saudi Arabia is based on the association of that genus with *Thamboceras* and *Spiroceras bifurcatum* (Quenstedt) (pl. 1, figs. 1-6) in the lower 5.5 meters of the middle part of the Dhruma Formation (fig. 2, 3); on its association at Sinai, Egypt, with *S. bifurcatum* (Quenstedt) and the ammonite genera *Oecotraustes* and *Leptosphinctes* (Arkell, 1952, p. 296); and on its association in Algeria with species of *Cadomites*, *Leptosphinctes*, and *Cleistosphinctes* that are characteristic of the *Strenoceras subfurcatum* zone at the base of the upper Bajocian in northwest Europe (Arkell and Lucas, 1953; Arkell, 1956, p. 264). Of these ammonites *Spiroceras bifurcatum* (Quenstedt) is characteristic of the lower and middle parts of the upper Bajocian (Arkell, 1952, p. 296); *Leptosphinctes* and *Cleistosphinctes* are known only from the upper Bajocian; and *Cadomites*, *Oecotraustes*, and *Spiroceras* are not known below the upper Bajocian. Whether the *Ermoceras* beds correlate only with the lowermost upper Bajocian, as suggested by Westermann (1965, p. 871), or with the entire upper Bajocian, is still undetermined.

The *Ermoceras* beds in Saudi Arabia were at first dated by Arkell (1952, p. 293-296) as "Early-Upper or late Middle Bajocian" because most of the above-cited age evidence was not then known, but he later dated the beds as definitely late Bajocian (Arkell, 1956, p. 300).

European stages		Stratigraphic units in central Saudi Arabia		Characteristic ammonites (this report)		Ammonite faunas (from Arkell, 1952)	Ranges of some ammonites in Saudi Arabia		
Jurassic	Oxfordian	Tuwayq Mountain Limestone	Upper part						
	Callovian		Lower part		<i>Pachyceras</i> , ? <i>Erymnoceras</i> , and <i>Erymnoceras</i> ( <i>Pachyerymnoceras</i> )		<i>Erymnoceras</i>	<i>Pachyceras</i> cf. <i>P. schloenbachii</i>  -----  <i>Erymnoceras philbyi</i>  -----  <i>Erymnoceras</i> cf. <i>E. philbyi</i>  -----  <i>Erymnoceras</i> ( <i>Pachyerymnoceras</i> ) cf. <i>E. (P.) jarryi</i>  -----  <i>Erymnoceras</i> ( <i>Erymnoceras</i> ) sp.  -----	
		Bathonian	Dhurma Formation	Upper	Hisyan Member	?	<i>Grossouvreia</i>		
	Atash Member								
	Middle					<i>Dhurmaites</i>	<i>Dhurmaites</i>	<i>Tulites</i> spp.  -----  <i>Micromphalites</i> spp.  -----  <i>Tulites</i> spp.  -----  <i>Ermoceras</i> spp.  -----  <i>Dorsetensia</i> spp.  -----	
				?		<i>Micromphalites</i> and <i>Thambites</i> (rare)	<i>Micromphalites</i>		<i>Clydoniceras pseudodiscus</i>  -----  <i>Thambites planus</i>  -----  <i>Thambites</i>  -----  <i>Thamboceras mirabile</i>  -----
				<i>Tulites</i>		<i>Tulites</i>	<i>Ermoceras</i>  -----  <i>Dorsetensia</i>  -----		
				?		<i>Thambites</i> and <i>Dhurmaites</i> (rare)			<i>Thambites</i>

FIGURE 3.—Correlation of some Jurassic ammonite faunas in central Saudi Arabia. Solid lines in right-hand column represent ammonite ranges established by Arkell (1952); dashed lines are ranges established in this report.

His earlier tentative assignment was influenced by the presence of a few poorly preserved ammonites that he compared (Arkell, 1952, p. 270, 271, 277) with species of *Stephanoceras*, *Teloceras*, and *Normannites* from the late middle Bajocian of northwest Europe. Of these, the specimens assigned by Arkell to *Stephanoceras* and *Teloceras* were later restudied by Westermann (1965, p. 870, 871) and reassigned to *Ermoceras*. The specimens assigned by Arkell to *Normannites* are herein refigured (pl. 1, figs. 9–12) to show that their generic identity is uncertain. Of course, the presence of these three genera with *Ermoceras* would not be surprising and would not be evidence of a middle Bajocian age considering that all three have been recorded from beds of late Bajocian age at many places (Arkell, 1956, p. 63, 99, 122, 176, 232, 263, 264, 483; Imlay, 1962, p. A4; Westermann, 1965, p. 871).

An early to middle Bathonian age determination for the lower three-fourths of the middle part of the

Dhurma Formation above the Dhibi Member was made by Arkell (1952, p. 297). The lowest beds, characterized by *Thambites*, were considered on the basis of stratigraphic position to be lower Bathonian or transitional into the Bajocian (Arkell, 1952, p. 297). The succeeding beds, characterized by *Tulites* and *Micromphalites*, were referred with confidence to the middle Bathonian on the basis of the ranges of those genera in northwest Europe (Arkell, 1952, p. 297; 1958, p. 236, 237; Torrrens, 1965, p. 52), although *Micromphalites* had been recorded from the lower Bathonian (Arkell, 1952, p. 297; 1958, p. 236).

The present studies, based on additional collections of ammonites, modify these age determinations only slightly. First, the basal few meters of the middle Dhurma Formation are definitely of late Bajocian age, as discussed previously, because they contain *Spiroceras bifurcatum* (Quenstedt), a species characteristic of the European zones of *Strenoceras subfurcatum* and *Garan-*

TABLE 2.—Geographic distribution of some Toarcian

(Locality descriptions are given in table 3. The geographic distribution of the KK

	Marrat Formation		Dhruma													
	Lower		Upper		Lower		Middle									
							Dhibi Member									
	Bouleiceras		Nejdia		Dorsetensia		Ermoceras		Spiroceras						Thambites	
	KK6-10.5+K1	KK6-14	Aramco S-1655	Aramco L-941	KK7-35	KK6	Aramco L-933	KK7-113	Aramco S-1058	KK7-130.5	KK7-131	KK7-132.3	KK7-133	KK8-basal	KK8-2	KK8-3
<i>Lytoceras?</i> sp.																
<i>Spiroceras bifurcatum</i> (Quenstedt)																
<i>annulatum</i> (Deshayes)																
<i>Protogrammoceras madagascariense</i> (Thevenin)																
sp.	X	X														
<i>Bouleiceras</i> sp.		X														
<i>Nejdia bramkampfi</i> Arkell			X	X												
<i>Dorsetensia</i> cf. <i>D. Hostraca</i> Buckman					X											
sp.						X										
<i>Normannites?</i> sp.									X							
<i>Thamboceras mirabile</i> Arkell										X						
<i>Thambites planus</i> Arkell																
cf. <i>T. planus</i> Arkell																
<i>Ermoceras mogharensis</i> H. Douville											X					
aff. <i>E. mogharensis</i> H. Douville											X					
<i>elegans</i> H. Douville												X				
cf. <i>E. elegans</i> H. Douville								X								
aff. <i>E. inermis</i> H. Douville													X			
sp.																
( <i>Telemoceras</i> cf. <i>E. (T) coronatoides</i> (H. Douville)							X									
<i>Micromphalites</i> cf. <i>M. elegans</i> Arkell																
cf. <i>M. pustuliferus</i> (H. Douville)																
cf. <i>M. busqueti</i> (de Grossouvre)																
sp.																
( <i>Clydomphalites</i> ) <i>clydomphalus</i> Arkell																
<i>Dhrumaites cardioceras</i> Arkell																
sp.																
<i>Tulites erymnoides</i> Arkell																
<i>Erymnoceras philbyi</i> Arkell																
cf. <i>E. philbyi</i> Arkell																
( <i>Erymnoceras</i> ) sp.																
( <i>Pachyerymnoceras</i> ) cf. <i>E. (P.) jarryi</i> (R. Douville)																
<i>Pachyeras</i> cf. <i>P. schloenbachii</i> (Roman)																
<i>Rollerites?</i> cf. <i>R. tenue</i> (Rollier)																
<i>Grossouria</i> sp.																

*tiana garantiana* (Arkell, 1952, p. 296). Second, the genus *Thambites* at the top of its range is associated with *Micromphalites* (loc. KK9-30 to -40) above the *Tulites* beds and is therefore, in part, of middle Bathonian age. Third, the record of *Clydoniceras* (Arkell, 1952, p. 282), a middle to late Bathonian genus (Arkell, 1951, p. 21; 1952, p. 304) in western Europe, at three localities in the upper part of the main range of *Thambites* below the *Tulites* beds (1952, p. 293) is good evidence of a middle Bathonian age for that part. On the basis of these age determinations, there are only about 19 meters of beds between the occurrences of *Spiroceras bifurcatum* and *Clydoniceras* to account for the lower Bathonian and perhaps the uppermost Bajocian.

In considering the age of the *Thambites* beds, no mention of *Clydoniceras* was made by Arkell (1952, p. 297), but neither did he question the presence of *Clydoniceras*

in association with *Thambites* (Arkell, 1952, p. 282). In the writer's opinion the specimens assigned to *Clydoniceras* by Arkell clearly belong to that genus rather than to *Thambites*, as shown by the presence of an acute unicarinate venter. It appears, therefore, that Arkell may have had some reservations about the age range of *Clydoniceras* in Arabia. If *Clydoniceras* arose from the late Bajocian *Thamboceras*, as Arkell (1952, p. 305-306) thought most probable, its earliest forms in Arabia might be as old as early Bathonian.

Arkell (1952, p. 293, 298) tentatively assigned a late Bathonian age to the *Dhrumaites* beds in the upper fourth of the middle Dhruma Formation on the basis that *Dhrumaites* greatly resembles the underlying middle Bathonian genus *Micromphalites* and probably belongs in the same Bathonian family, the Clydoniceratidae. Doubts concerning this relationship were ex-

series is shown in figure 1, and the stratigraphic distribution is shown in figure 2]

[illegible]

A middle Callovian age for most of the upper part of the Dhruma Formation is assured by the presence of the ammonites *Pachyceras* cf. *P. schloenbachi* (Roman), *Erymnoceras philbyi* Arkell, *E. (Pachyerymnoceras)* cf. *E. (P.) jarryi* (R. Douvillé), *E. (Erymnocerites)* sp., *Rollierites* cf. *R. tenue* (Rollier), and *Grossouvria* sp. (figs. 2, 3). These ammonites were collected from 11 to 21 meters above the base of the upper part of the Dhruma, which is 89 meters thick, and in the Atash Member which is 25 meters thick. The faunule is virtually the same as that found in 25–40 meters of soft argillaceous limestone at the base of the Tuwazyq Mountain Limestone, which contains three of the same species and corresponds likewise to the *Erymnoceras coronatum* zone of northwest Europe (Arkell, 1952, p. 289–291, 298).

Other ammonites of middle Callovian age, including *Erymnoceras philbyi* Arkell (loc. L-919A), *E. (Pachyerymnoceras)* cf. *E. (P.) jarryi* (R. Douvillé) (loc. L-919B), and *E. cf. E. philbyi* Arkell (loc. L-942), were collected from the upper part of the Dhurma Formation, either near the base of the Tuwayq Mountain Limestone, or near the Tuwayq Mountain escarpment. Presumably these fossils were obtained near the top of the formation in the Hisyan Member, or its lateral equivalents, and at an appreciably higher stratigraphic position than those from the Atash Member.

#### GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION

Detailed descriptions of Jurassic fossil localities in central Saudi Arabia are given in table 3. The positions of the described localities relative to geographic and cultural features can be obtained by consulting several U.S. Geological Survey Miscellaneous Geologic Investigations Maps (Bramkamp and others, 1956; Bramkamp and Ramirez, 1958; and Bramkamp and others, 1963). Only those localities in the Aramco S series that are referred to in this report or that were not described previously by Bramkamp and Steineke (in Arkell, 1952, p. 252-256) are described herein. The occurrences of the fossils by localities are indicated in table 2.

TABLE 3.—Some Jurassic fossil localities in central Saudi Arabia

[The approximate positions of the Aramco S series of localities, collected by various geologists of the Arabian-American Oil Co. between 1933 and 1952, are shown on sketch maps in Bramkamp and Steineke (1952, figs. 1, 2). The Aramco L series are from the same general area as the S series, and the positions of the KK series are shown herein in figure 1. In the KK series, the figure that follows the hyphen indicates meters above the base of the sample section (fig. 1).]

Collector's field No.	Stratigraphic assignment, description of locality, characteristic ammonites, collector, and year of collection
Aramco L-916A <sup>1</sup> ----	Tuwayq Mountain Limestone, 18 meters above base of cliff. Lat 26°21'32" N., long 44°48' E., Wadi Aruma quadrangle, Saudi Arabia. <i>Pachyceras</i> cf. <i>P. schloenbachi</i> (Roman).
Aramco L-919A----	Dhurma Formation, upper part, near base of Tuwayq Mountain escarpment. Lat 25°41'59.25" N., long 45°12'27.75" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Erymnoceras philbyi</i> Arkell.
Aramco L-919B----	Dhurma Formation, upper part, 1 meter higher than Aramco L-919A at same locality. <i>Erymnoceras (Pachyerymnoceras)</i> cf. <i>E. (P.) jarryi</i> (R. Douvillé).
Aramco L-920-----	Dhurma Formation, middle part, from gypsiferous shale. Lat 24°52'38.50" N., long 43°53'51.50" E., Wadi Aruma quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from <i>Dhurmaites</i> zone of Bramkamp and Steineke (in Arkell, 1952, p. 247).
Aramco L-921-----	Dhurma Formation, middle part, from 2.2 meters below top of bench of chalky limestone. Lat 24°52'51" N., long 45°54'04.50" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Tulites erymnoides</i> Arkell from the <i>Dhurmaites</i> or <i>Micromphalites</i> zone.

See footnotes at end of table.

TABLE 3.—Some Jurassic fossil localities in central Saudi Arabia—Continued

Collector's field No.	Stratigraphic assignment, description of locality, characteristic ammonites, collector, and year of collection
Aramco L-929-----	Dhurma Formation, probably upper part, from scree slopes. Lat 24°55'16" N., long 45°59'55" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Erymnoceras philbyi</i> Arkell and <i>Rollierites</i> cf. <i>R. tenue</i> (Rollier).
Aramco L-931A----	Dhurma Formation, middle part. Lat 24°11'04" N., long 46°17'31.50" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from <i>Thambites</i> zone.
Aramco L-931B----	Dhurma Formation, middle part. Lat 24°11'04" N., long 46°17'31.50" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from <i>Thambites</i> zone.
Aramco L-932-----	Dhurma Formation, middle part. Lat 24°12'49" N., long 46°17'05" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the <i>Thambites</i> zone.
Aramco L-933-----	Dhurma Formation, lower part, probably below base of the Dhiki Member. Lat 24°10'45" N., long 46°13'20" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Ermoceras (Telermoceras)</i> cf. <i>E. (T.) coronatoides</i> (H. Douvillé).
Aramco L-941-----	Marrat Formation, upper part, from limestone beds above shale. Lat 24°10'53" N., long 46°09'27.25" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Nejdia bramkampii</i> Arkell.
Aramco L-942-----	Dhurma Formation at top in chalky beds below contact with Tuwayq Mountain Limestone. Lat 23°14'32" N., long 46°35'17" E., Southern Tuwayq quadrangle, Saudi Arabia. <i>Erymnoceras</i> cf. <i>E. philbyi</i> Arkell.
Aramco S-1058-----	Dhurma Formation, lower part, from 14.6 to 15.6 meters below top of Dhibi Member. Lat 23°12.8' N., long 46°25.8' E., Southern Tuwayq quadrangle, Saudi Arabia. Equals locality 61 of Bramkamp and Steineke (in Arkell, 1952, p. 256). <i>Normannites?</i> sp. Collector unknown.
Aramco S-1063-----	Dhurma Formation, middle part, 10 meters above Dhibi Member and 110.6 meters above base of formation, gypsiferous light-gray to cream-colored fine-grained limestone. Lat 23°31'12" N., long 46°16'24" E., Southern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the <i>Thambites planus</i> zone. Collected by E. L. Berg, R. P. Myers, W. T. Slort, and R. A. Bramkamp, 1945.
Aramco S-1150-----	Dhurma Formation, middle part. Lat 24°48'43" N., long 46°58'36" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> cf. <i>M. busqueti</i> (de Grossouvre) in the <i>Micromphalites</i> zone of Bramkamp and Steineke (in Arkell, 1952, p. 248). Collected by D. A. Holm and M. P. Yackel, 1947.
Aramco S-1197-----	Tuwayq Mountain Limestone, 22.4 meters above base. Lat 25°02.4' N., long 45°53.1' E., Northern Tuwayq quadrangle, Saudi Arabia. Equals locality 32 of Bramkamp and Steineke (in Arkell, 1952, p. 254). <i>Erymnoceras</i> cf. <i>E. philbyi</i> Arkell and <i>Pachyceras</i> cf. <i>P. schloenbachi</i> (Roman). Collector unknown.

TABLE 3.—Some Jurassic fossil localities in central Saudi Arabia—Continued

Collector's field No.	Stratigraphic assignment, description of locality, characteristic ammonites, collector, and year of collection
Aramco S-1198-----	Tuwayq Mountain Limestone, 15.6 meters above base. Same location as Aramco S-1197. Equals locality 31 in Bramkamp and Steineke (in Arkell, 1952, p. 254). <i>Erymnoceras philbyi</i> Arkell. Collector unknown.
Aramco S-1487-----	Dhurma Formation, middle part, about 6 meters above Dhibi Member, on south side of Wadi Birk. Lat 23°11'00" N.; long 46°26'54" E., Southern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell in <i>Thambites</i> zone. Collected by R. A. Bramkamp and N. J. Sander, 1948.
Aramco S-1508-----	Dhurma Formation, top of middle part, 5.3 meters of beds, below bench-forming brown oolitic unit and 80-85 meters above base of <i>Micromphalites</i> -bearing beds, 5.6 kilometers S. 41° W. of Khashm Hisan. Lat 25°02.6' N., long 45°50' E., Northern Tuwayq quadrangle, Saudi Arabia. Equals locality 29 of Bramkamp and Steineke (in Arkell, 1952, p. 254) <i>Dhurmaites cardiocera-toides</i> Arkell. Collector unknown.
Aramco S-1607-----	Tuwayq Mountain Limestone, 60.5-62.5 meters below top of the lower coral-bearing unit. Lat 25°18.6' N., long 45°45.9' E., Northern Tuwayq quadrangle, Saudi Arabia. Equals locality 21 of Bramkamp and Steineke (in Arkell, 1952, p. 253). <i>Erymnoceras</i> cf. <i>E. philbyi</i> Arkell. Collector unknown.
Aramco S-1611-----	Tuwayq Mountain Limestone, lower part. Lat 25°02.5' N., long 45°40.4' E., Northern Tuwayq quadrangle, Saudi Arabia. Equals locality 35 of Bramkamp and Steineke (in Arkell, 1952, p. 254). <i>Erymnoceras</i> cf. <i>E. philbyi</i> Arkell. Collector unknown.
Aramco S-1655-----	Marrat Formation, about 15-17 meters below top; from slope covered with scree of light-colored limestone. Lat 24°04'06"-54" N., long 46°12'00"-54" E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Nejdia bramkampii</i> Arkell. Collected by R. B. Carr, M. C. Coffield, and R. A. Bramkamp, 1951.
Aramco S-1804-----	Tuwayq Mountain Limestone(?); from granular cream-colored chalky limestone containing thin-lensing beds of sparsely oolitic limestone, about 5 kilometers northwest of town of Zilfi. Lat 26°21'06" N., long 44°47'13" E., Wadi Aruma quadrangle, Saudi Arabia. <i>Erymnoceras philbyi</i> Arkell. Collected by S. J. Roach and W. M. Furnish, 1952.
KK6 <sup>2</sup> -10.5+K1 (mixed)-----	Marrat Formation, lower member, about 20 meters above base of member. Lat 24°14' N., long 46°06' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Protogrammoceras</i> sp.
KK6-14-----	Marrat Formation, top of lower member, 23.5 meters above base of formation. Lat 24°14' N., long 46°06' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Protogrammoceras madagascariense</i> (Thevenin) and <i>Bouleiceras</i> sp.

See footnotes at end of table.

TABLE 3.—Some Jurassic fossil localities in central Saudi Arabia—Continued

Collector's field No.	Stratigraphic assignment, description of locality, characteristic ammonites, collector, and year of collection
KK6-----	Dhurma Formation, lower part, upper one-third of yellow marl below Dhibi Member, above measured section shown in figure 1. Lat 24°14' N., long 46°7' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Dorseteria</i> sp.
KK7-35-----	Dhurma Formation, lower part, 94 meters below top of Dhibi Member and 26.8 meters above base of formation. Lat 24°11' N., long 46°11' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Dorsetensia</i> cf. <i>D. lostraca</i> Buckman.
KK7-113-----	Dhurma Formation, lower part, 16 meters below top of Dhibi Member. Lat 24°11' N., long 46°11' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Ermoceras</i> cf. <i>E. elegans</i> Douvillé from the <i>Ermoceras</i> zone.
KK7-130.5-----	Dhurma Formation, middle part, 1.5 meters above Dhibi Member. Lat 24°12' N., long 46°11' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thamboceras mirabile</i> Arkell and <i>Ermoceras</i> aff. <i>E. mogharensis</i> Douvillé from the top of the <i>Ermoceras</i> zone.
KK7-131-----	Dhurma Formation, middle part, 2 meters above Dhibi Member. Lat 24°12' N., long 46°11' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Ermoceras mogharensis</i> Douvillé and <i>Spiroceras annulatum</i> (Deshayes) from the top of the <i>Ermoceras</i> zone.
KK7-132.3-----	Dhurma Formation, middle part, 3.3 meters above Dhibi Member. Lat 24°11' N., long 46°11' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Ermoceras elegans</i> Douvillé, <i>E. aff. E. mogharensis</i> Douvillé from the top of the <i>Ermoceras</i> zone.
KK7-133-----	Dhurma Formation, middle part, 4 meters above Dhibi Member. Lat 24°11' N., long 46°11' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Ermoceras</i> sp. from the top of the <i>Ermoceras</i> zone.
KK7-135.1-----	Dhurma Formation, middle part, 6.1 meters above Dhibi Member. Lat 24°11' N., long 46°11' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the base of the <i>Thambites</i> zone.
KK8-basal-----	Dhurma Formation, base of middle part just above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Ermoceras</i> sp. and <i>Spiroceras bifurcatum</i> (Quenstedt) from the top of the <i>Ermoceras</i> zone.
KK8-2-----	Dhurma Formation, middle part, 4.5 meters above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Ermoceras mogharensis</i> Douvillé from the top of the <i>Ermoceras</i> zone.
KK8-3-----	Dhurma Formation, middle part, 5.5 meters above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Spiroceras bifurcatum</i> (Quenstedt) from the top of the <i>Ermoceras</i> zone.

TABLE 3.—Some Jurassic fossil localities in central Saudi Arabia—Continued

Collector's field No.	Stratigraphic assignment, description of locality, characteristic ammonites, collector, and year of collection
KK8-6-----	Dhurma Formation, middle part, 8.5 meters above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Dhurmaites</i> sp. from the <i>Thambites</i> zone.
KK8-23-----	Dhurma Formation, middle part, 25.5 meters above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the <i>Thambites</i> zone.
KK8-27.7-----	Dhurma Formation, middle part, 30.2 meters above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the <i>Thambites</i> zone.
KK8-34-----	Dhurma Formation, middle part, 36.5 meters above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the <i>Thambites</i> zone.
KK8-35 to 38-----	Dhurma Formation, middle part, 37.5–40.5 meters above Dhibi Member. Lat 24°11' N., long 46°17' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the <i>Thambites</i> zone.
KK9-14-----	Dhurma Formation, middle part, 87 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> sp. and <i>Thambites planus</i> Arkell from the <i>Micromphalites</i> zone.
KK9-15.5-----	Dhurma Formation, middle part, 85.5 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> cf. <i>M. busqueti</i> (de Grossouvre), <i>M. cf. M. elegans</i> Arkell, <i>M. cf. M. pustuliferus</i> (Douville), and <i>M. (Clydomaphalites) clydocromphalus</i> Arkell from the <i>Micromphalites</i> zone.
KK9-16-----	Dhurma Formation, middle part, 85 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> cf. <i>M. busqueti</i> (de Grossouvre), <i>M. cf. M. elegans</i> Arkell, and <i>M. sp.</i> from the <i>Micromphalites</i> zone.
KK9-18 to -19-----	Dhurma Formation, middle part, 83–84 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> sp. from the <i>Micromphalites</i> zone.
KK9-20.5-----	Dhurma Formation, middle part, 80.5 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> cf. <i>M. pustuliferus</i> (Douville) from the <i>Micromphalites</i> zone.
KK9-21-----	Dhurma Formation, middle part, 80 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> cf. <i>M. pustuliferus</i> (Douville) and <i>M. sp. juv.</i> from the <i>Micromphalites</i> zone.

TABLE 3.—Some Jurassic fossil localities in central Saudi Arabia—Continued

Collector's field No.	Stratigraphic assignment, description of locality, characteristic ammonites, collector, and year of collection
KK9-23-----	Dhurma Formation, middle part 78 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> cf. <i>M. elegans</i> Arkell from the <i>Micromphalites</i> zone.
KK9-30 to 40-----	Dhurma Formation, middle part, 61–71 meters below base of Atash Member. Lat 24°11' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Thambites planus</i> Arkell from the <i>Micromphalites</i> zone.
KK9-52-----	Dhurma Formation, middle part, 49 meters below base of Atash Member. Lat 24°12' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Micromphalites</i> sp. from the <i>Micromphalites</i> zone.
KK9-73-----	Dhurma Formation, middle part, 28 meters below base of Atash Member. Lat 24°12' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Dhurmaites cardioceratoides</i> Arkell from the <i>Dhurmaites</i> zone.
KK9-112-----	Dhurma Formation, upper part, 11 meters above base of Atash Member. Lat 24°12' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Grossouvreia</i> sp.
KK9-112 to 120----	Dhurma Formation, upper part, 11–19 meters above base of Atash Member. Lat 24°12' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Pachyceras</i> cf. <i>P. schloenbachii</i> (Roman).
KK9-117-----	Dhurma Formation, upper part, 16 meters above base of Atash Member. Lat 24°12' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Grossouvreia</i> sp. and <i>Lytoceras?</i> sp.
KK9-119.5-----	Dhurma Formation, upper part, 18.5 meters above base of Atash Member. Lat 24°12' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Erymnoceras (Erymnocerites)</i> sp.
KK9-120.5-----	Dhurma Formation, upper part, 19.5 meters above base of Atash Member. Lat 24°12' N., long 46°19' E., Northern Tuwayq quadrangle, Saudi Arabia. <i>Erymnoceras philbyi</i> Arkell.

<sup>1</sup> All Aramco L locality collections were made by N. M. Layne, Jr., and H. A. McClure in 1961.

<sup>2</sup> All KK locality collections were made by P. M. Kier, E. G. Kauffman, R. W. Powers, H. A. McClure, and C. D. Redmond in 1962.

## SYSTEMATIC DESCRIPTIONS

Family SPIROCERATIDAE Hyatt, 1900

Genus SPIROCERAS Quenstedt, 1858

*Spiroceras bifurcatum* (Quenstedt<sup>1</sup>)

Plate 1, figures 1–6

For synonymy see Potonie, 1929, p. 230, 235–245.

Three worn internal molds of *Spiroceras* bear ribbing of average coarseness for the species *S. bifurcatum* (Quenstedt, 1858, pl. 55, figs. 1–12; 1886, pl. 70, figs. 27–44; Roman and Petouraud, 1927, pl. 3, figs. 13–20;



pl. 4, figs. 1–3, pl. 5, figs. 7–11; and Potonie, 1929, pl. 17, figs. 4–25, pl. 18, figs. 26–28). All ribs incline slightly adorally on the flanks, become stronger ventrally, and terminate on the venter in prominent tubercles that bound a smooth midventral area. Except on one much swollen rib, there are only faint indications of a second row of weak tubercles high on the flanks.

*Hypotypes*.—USNM 163608–163610.

*Occurrence*.—Dhurma Formation, lower 5.5 meters of middle part just above Dhibi Member at localities KK8-basal and KK8–3.

***Spiroceras annulatum* (Deshayes)**

Plate 1, figures 7, 8.

For synonymy see Roman and Petouraud, 1927, p. 33; Potonie, 1929, p. 240.

On the flanks of one internal mold of *Spiroceras* there are fairly fine, closely spaced, adorally inclined ribs that become stronger ventrally. All ribs arch forward on the venter and are reduced considerably in strength along the midventral line. All ribs are swollen on the venter but are not distinctly tuberculate.

This specimen is closely similar to *S. annulatum* (Deshayes) as illustrated by d'Orbigny (1850, p. 577, pl. 225, figs. 1–7) and Roman and Petouraud (1927, p. 33, pl. 3, fig. 21, pl. 5, figs. 15–19). These authors show that the species in its early growth stages bears weak ventral tubercles. The presence of weak tubercles on the adult growth stages of some specimens is illustrated by Potonie (1929, pl. 17, figs. 24, 25), who notes (1929, p. 241) that on other specimens, ventral tubercles become weak during growth. Apparently, *S. annulatum* is distinguished from *S. bifurcatum* by having finer and denser ribbing and by the venter of the adult growth stages becoming nontuberculate or only weakly tuberculate.

The specimen illustrated is nearly identical in appearance with two specimens of *Spiroceras* from Gebel Maghara, Sinai, illustrated by H. Douvillé (1916, pl. 3, figs. 11a, b, 13a, b) as *Ancyloceras tenui* d'Orbigny.

*Hypotype*.—USNM 163611

*Occurrence*.—Dhurma Formation, from base of middle part, about 2 meters above the Dhibi Member at locality KK7–131 in association with *Ermoceras mogharensis* Douvillé.

**Family STEPHANOCERATIDAE Neumayr, 1875**  
**Genus NORMANNITES Munier-Chalmas, 1892**

***Normannites?* sp.**

Plate 1, figures 9–12

Two worn internal molds from the *Ermoceras*-bearing beds in the upper part of the lower Dhurma For-

mation were assigned to *Normannites* by Arkell (1952, p. 277, 295). The whorls are ovate in section, higher than wide, and embrace about half of the preceding whorls. The primary ribs are fairly strong and divide a little below the middle of the flanks into thinner, higher secondary ribs that cross the venter transversely. A few secondary ribs arise freely on the flanks. On the largest specimen the secondary ribs appear to be slightly reduced in strength along the midline of the venter. Tubercles are not evident on the flanks. Their absence, as well as the thinning of ribs on the venter, may be due to weathering, but preclude a definite assignment to *Normannites* until better preserved specimens are found.

*Figured specimens*.—USNM 132147.

*Occurrence*.—Dhurma Formation, Dhibi Member, from 14.6 to 15.6 meters below top, at Aramco locality S-1058.

**Family CLYDONICERATIDAE Buckman, 1924**  
**Genus DHRUMAITES Arkell, 1952**

***Dhurmaites cardioceratoides* Arkell**

Plate 1, figures 13–15; plate 3, figures 5, 8; plate 4

*Dhurmaites cardioceratoides* Arkell, 1952, Royal Soc. London Philos. Trans., ser. B, v. 236, no. 633, p. 288, pl. 25, figs. 2, 8, text fig. 10 on p. 289.

There are two large septate specimens in the collections, and the one illustrated is much more complete and about the same size as the holotype. The species is characterized by an oxycone shell, a lanceolate whorl section, nearly smooth outer septate whorls, faint broad gently flexuous ribs that disappear adorally, a vertical umbilical wall that rounds rather abruptly into the flanks, and a narrow umbilicus that widens slightly on the adoral half of the largest septate whorl. The body chamber is unknown except possibly for the imprint of the umbilical seam on the entire largest septate whorl. This imprint occurs constantly at about one-fifth of the height of the flank, which shows that the umbilicus does not become increasingly eccentric adorally.

The suture line has a broad first lateral saddle, an irregular broad flat first lateral lobe and a bifid second lateral lobe. The first and second lateral saddles become lower and broader during growth and at a whorl height of 145 mm are appreciably broader than on the type specimens at a comparable height (Arkell, 1952, fig. 10 on p. 289).

The illustrated specimen at a diameter of 272 mm has a whorl height of 145 mm, a whorl thickness of 75 mm, and an umbilical width of 35 mm. At a diameter of 225 mm, the whorl height is 123 mm, the whorl thickness is 56 mm, and the umbilical width is 25 mm.

The specimens from locality KK9-73, as well as one from Aramco locality S-1508 (pl. 3, fig. 9), differ from the primary types by having broader saddles and by losing all trace of ribbing at much smaller diameter. These differences may not be of specific importance considering that *Dhrumaites* belongs to a family noted for having highly variable sutures, that the range of variability in *Dhrumaites* is not known, and that all known specimens are more or less corroded.

*Hypotype*.—USNM 163612.

*Occurrence*.—Dhruma Formation, middle part, 28 meters below base of Atash Member at locality KK9-73 (fig. 2, table 3). The specimens of *Dhrumaites cardioceratoides* described by Arkell (1952, p. 254, 255, 288) were all obtained from the upper 34 meters of the middle part of the Dhruma Formation. The holotype was obtained at Aramco locality S-1508 in the upper 7 meters of the middle part of the Dhruma Formation.

*Dhrumaites* sp.

Plate 3, figures 6, 7, 9

One small internal mold of *Dhrumaites* (pl. 3, figs. 6, 7) is worth recording because it was found (loc. KK8-6) only 8.5 meters above the Dhibi Member of the Dhruma Formation, or about 126 meters below the lowest occurrence of *D. cardioceratoides* Arkell. The specimen has a lanceolate whorl section, a small umbilicus, a vertical umbilical wall that rounds abruptly into the flanks, and lacks ribbing. The suture line, much corroded on the lower fourth of the flanks, is characterized by broad saddles and a broad, irregular first lateral lobe. The general pattern of the suture line is similar to that of *D. cardioceratoides* Arkell as herein illustrated (pl. 4).

The specimen differs from *D. cardioceratoides* Arkell at a comparable size (Arkell, 1952, pl. 25, figs. 2a, b, text fig. 10 on p. 289) by being more compressed, by lacking ribbing, and by having lower and broader saddles. Its broad first lateral saddle is similar to that on a specimen (pl. 3, fig. 9), labeled *Dhrumaites* sp. by Arkell, that was obtained with the holotype of *D. cardioceratoides* Arkell at Aramco locality S-1508. Both specimens could be variants of that species.

*Figured specimens*.—USNM 163613, 163614.

*Occurrence*.—Dhruma Formation, near base of middle part, 8.5 meters above Dhibi Member at locality KK8-6; near top of middle part at Aramco locality S-1508.

The specimen of *Dhrumaites* at locality KK8-6 was collected from a flat on which the highest beds exposed are in the lower part of the middle Dhruma Formation. The flat is separated by dry gulches (wadis) on the north and east from exposures of the upper part of the

middle Dhruma Formation which hitherto have furnished all specimens of *Dhrumaites*. Because of these gulches and because the top of the KK8 sequence is only 63.5 meters above the top of the Dhibi Member, it seems unlikely that the ammonite at locality KK8-6 could have been derived as float from the upper part of the middle Dhruma, or even as high as the beds characterized by *Micromphalites*.

Family PACHYGERATIDAE Buckman, 1918

Genus ERYMNOCERAS Hyatt, 1900

*Erymnoceras philbyi* Arkell

Plate 2, figures 3-9

*Erymnoceras philbyi* Arkell, 1952, Royal Soc. London Philos. Trans., ser. B, v. 236, no. 633, p. 290, pl. 29, figs. 1-3.

Since this species was described by Arkell (1952, p. 290), five small specimens have been obtained from the Tuwayq Mountain Limestone and one small specimen from about 19.5 meters above the base of the upper part of Dhruma Formation, near the top of the Atash Member.

This ammonite from the Dhruma Formation was at first identified by the writer with *Tulites erymnoides* Arkell (1952, p. 284, pl. 25, figs. 1, 4), which species was placed by Arkell in *Tulites* rather than in *Erymnoceras* for stratigraphic reasons. It differs from *T. erymnoides*, however, by its ribs arching only gently forward on the venter instead of being strongly inclined forward. Its present identification with *E. philbyi* Arkell is based on close resemblances to small specimens of that species as herein illustrated.

These specimens have coronate whorls, acute and rather closely spaced umbilical tubercles, and fairly broad ribs that become stronger ventrally. Most of the ribs arise in pairs from the umbilical tubercles, but a few arise by threes, and some are single.

*E. philbyi* Arkell is possibly represented (pl. 2, figs. 12, 13), also, by one adult (Aramco loc L-942) that resembles the holotype (Arkell, 1952, pl. 29, fig. 1a) in size, whorl shape, and coiling but differs in having coarse simple ribs instead of forked ribs on the adoral part of the body chamber.

*Types*.—Hypotypes, USNM 163615-163617.

*Occurrence*.—Tuwayq Mountain Limestone at Aramco localities S-1198 and S-1804; Dhruma Formation, about 19.5 meters above base of Atash Member at locality KK9-120.5; Dhruma Formation, upper part at Aramco localities L-919A and L-929. Probably represented also in Tuwayq Mountain Limestone at Aramco localities S-1197, S-1607, and S-1611. Possibly present near top of Dhruma Formation at Aramco locality L-942.

Subgenus **ERYMNOCERITES** Jeannet, 1951*Erymnoceras* (*Erymnocerites*) sp.

Plate 2, figures 10, 11

One small fragment has a subovate whorl section that is a little wider than high. The flanks converge gently from the umbilicus to a moderately rounded venter. The umbilicus apparently was moderate in width. The ribs incline slightly forward on the flanks and cross the venter transversely. The primary ribs are short, are swollen at the umbilicus, and divide at one-fourth to one-third of the height of the flanks into two or three weaker but fairly sharp, secondary ribs. A few secondary ribs arise freely at or above the zone of furcation. The secondary ribs become slightly broader ventrally.

This specimen bears ribbing similar to that on the smaller whorls of *E. (Erymnocerites) leuthardti* Rollier (Jeannet, 1951, p. 122, pls. 41, 42) but has much less strongly projected secondary ribs and probably a narrower whorl section. It differs from *Erymnoceras philbyi* Arkell by being much more compressed and by lacking prominent umbilical tubercles.

*Figured specimen*.—USNM 163619.

*Occurrence*.—Dhurma Formation, upper part, 18.5 meters above base of Atash Member at locality KK 9-119.5.

Subgenus **PACHYERYMNOCERAS** Breistroffer, 1947*Erymnoceras* (*Pachyerymnoceras*) cf. *E. (P.) jarryi* (R. Douvillé)

Plate 2, figures 1, 2

cf. *Pachyceras jarryi* R. Douvillé, 1912, Soc. Géol. France Mém. 45, v. 19, p. 37, pl. 7, figs. 10, 10a.

cf. *Erymnoceras* cf. *E. jarryi* (R. Douvillé) Arkell, 1952, Royal Soc. London Philos. Trans., ser. B, v. 236, no. 633, p. 290, pl. 29, figs. 4a, b.

The species is probably represented by one internal mold of which about one-fourth is septate, coronate, and only slightly compressed laterally. The nonseptate part is considerably crushed laterally and, consequently, is retracted appreciably from the next inner septate whorl. The mold bears coarse widely spaced ribs that on the septate part arise in pairs from prominent umbilical tubercles and arch gently forward on the venter. On the nonseptate part the tubercles weaken adorally, most ribs arise singly instead of in pairs, and the single ribs alternate with ribs that begin freely near the middle of the flanks. All ribs become equally strong ventrally and arch gently forward on the venter.

This specimen differs from the holotype of *E. jarryi* (R. Douvillé) mainly in being a little smaller. It has

comparable coarse ribs that branch in a similar manner and, before crushing, was probably as involute.

*Figured specimen*.—USNM 163620.

*Occurrence*.—Dhurma Formation, upper part, at Aramco locality L-919B.

Genus **PACHYCERAS** Bayle, 1878*Pachyceras* cf. *P. schloenbachi* (Roman)

Plate 1, figures 18-21

cf. *Stepheoceras schloenbachi* Roman, 1930, Lyon Univ. Lab. Géologie Travaux, pt. 14, mém. 11, p. 173, pl. 13, figs. 6, 6a.

*Pachyceras* cf. *P. schloenbachi* (Roman). Arkell, 1952, Royal Soc. London Philos. Trans., ser. B, v. 236, no. 633, p. 291, pl. 30, figs. 1a, b.

This species is represented in available collections by three specimens, of which the largest two resemble the specimen figured by Arkell (1952, pl. 30, figs. 1a, b). The large illustrated specimen bears faint primary ribs on the lower parts of the flanks and more numerous, broad secondary ribs on the upper parts of the flanks. These secondaries incline slightly forward on the flanks and then cross the venter transversely without reduction in strength.

The small illustrated specimen has not been compressed. The whorl section is ovate, slightly higher than wide. The flanks are flattened and converge gently to a moderately narrow venter. The umbilicus is fairly narrow. The umbilical wall is vertical below but rounds evenly into the flanks. The primary ribs are broad, low to faint, and divide at or a little below the middle of the flanks. Some secondary ribs arise freely on the upper part of the flanks. All secondary ribs are stronger than the primary ribs and become higher and broader ventrally.

The specimen shown on plate 1, figures 18, 19 at a diameter of 22 mm has a whorl height of 10.5 mm, a whorl thickness of 10 mm, and an umbilical width of 5 mm.

*Figured specimens*.—USNM 163621, 163622.

*Occurrences*.—Dhurma Formation, from 11 to 19 meters above base of Atash Member at locality KK9-112 to -120; Tuwayq Mountain Limestone at localities L-916A and Aramco S-1197.

Genus **ROLLIERITES** Jeannet, 1951*Rollierites*? cf. *R. tenue* (Rollier)

Plate 1, figures 16, 17

cf. *Rollierites tenue* (Rollier). Jeannet, 1951, Beitr. Geologie Schweiz Geophysik. Ser., Lf. 13, v. 5, p. 126, pl. 47, figs. 8, 9, text fig. 299 on p. 127.

One small laterally compressed internal mold appears to be fairly evolute. Its primary ribs are moderately

strong, are swollen near the umbilicus, and pass into pairs of equally strong secondary ribs at about one-fourth to one-third of the height of the flanks. Its secondary ribs incline forward to the flanks, arch gently forward on the venter, and become stronger ventrally. A few secondary ribs are loosely connected with the primary ribs. The adapical end of the mold, which is least compressed, has a whorl height of 13 mm and a whorl thickness of 10 mm.

The ribbing on this species is similar to that on *Rollierites tenue* (Rollier) (Jeannet, 1951, p. 126, pl. 47, figs. 8, 9) and on *R. richei* (Roman) (Jeannet, 1951, p. 124; Roman, 1930, p. 172, text fig. 3). Its whorl section, as preserved, appears to be a little thinner than that of those species.

*Figured specimen*.—USNM 163623.

*Occurrence*.—Dhruma Formation at Aramco locality L-929.

Family PERISPHINCTIDAE Steinmann, 1890

Genus GROSSOUVRIA Siemiradzki, 1898

*Grossouvria* sp.

Plate 3, figures 1-4

The genus *Grossouvria* is represented by two fragmentary specimens. One of these is an internal mold and the other retains considerable shelly material. Both bear strong, moderately spaced, adorally inclined primary ribs. These ribs divide above the middle of the flanks into pairs of equally strong secondary ribs that recurve backward on the upper parts of the flanks and cross the venter transversely. Some secondary ribs are loosely connected with the primary ribs. The internal mold shows parts of two whorls, has evolute coiling, and bears one deep constriction; its whorl section is ovate and slightly wider than high, and its ribs are slightly reduced in strength along the midline of the venter. The specimen that retains some shell bears a lateral lappet and its ribs are not reduced in strength on the venter.

This species closely resembles some of the small variants of *Grossouvria curvicosta* (Oppel) illustrated by Pfaehler-Erath (1938, pl. 1, figs. 1a, b, 2a, b) in size, shape, and ornamentation.

*Figured specimens*.—USNM 163624, 163625.

*Occurrences*.—Dhruma Formation, upper part, from 11 to 16 meters above base of Atash Member at localities KK9-112 and -117.

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**PLATES 1-4**

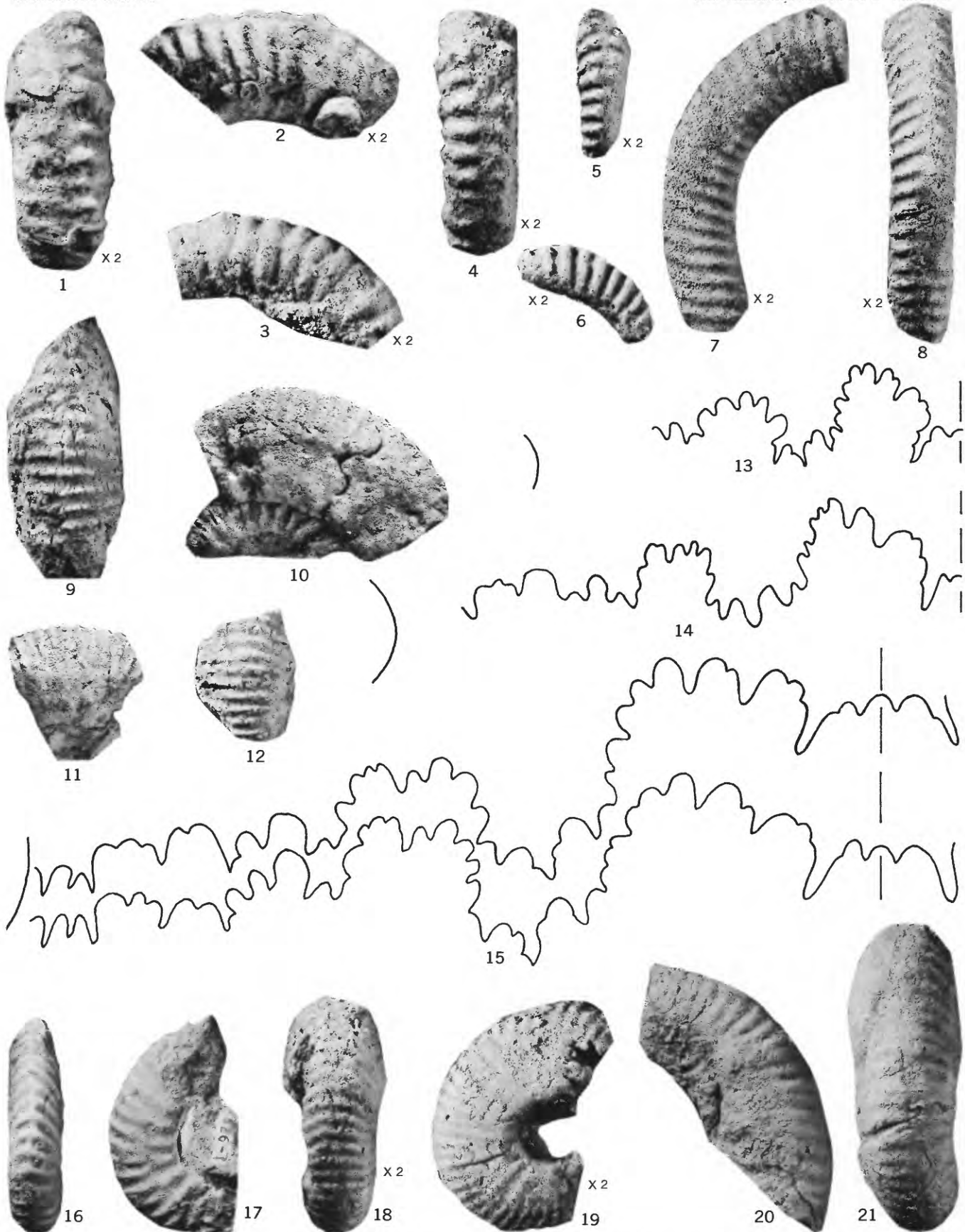
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## PLATE 1

[All figures are natural size unless otherwise indicated on plate]

- FIGURES 1-6. *Spiroceras bifurcatum* (Quenstedt) (p. D10).  
1, 2. Ventral and lateral views of hypotype, USNM 163610 from locality KK8-3. Dhurma Formation, near base of middle part.  
3, 4. Lateral and ventral views of hypotype, USNM 163609 from locality KK8-3. Dhurma Formation, near base of middle part.  
5, 6. Ventral and lateral views of hypotype, USNM 163608 from locality KK8-basal. Dhurma Formation, at base of middle part.
- 7, 8. *Spiroceras annulatum* (Deshayes) (p. D 11).  
Lateral and ventral views of hypotype, USNM 163611 from locality KK7-131. Dhurma Formation, near base of middle part.
- 9-12. *Normannites?* sp. (p. D11).  
Ventral (9, 12) and lateral (10, 11) views of worn specimens, USNM 132147 from Aramco locality S-1058. Dhurma Formation, near top of lower part, in Dhibi Member.
- 13-15. *Dhurmaites cardioceratoides* Arkell (p. D11).  
Suture lines drawn at whorl heights of 66, 88, and 145 mm respectively on hypotype USNM 163612 (see pl. 4), from locality KK9-73. Dhurma Formation, near top of middle part.
- 16, 17. *Rollierites?* cf. *R. tenue* (Rollier) (p. D13).  
Ventral and lateral views of specimen, USNM 163623 from Aramco locality L-929. Dhurma Formation, probably upper part.
- 18-21. *Pachyceras* cf. *P. schloenbachi* (Roman) (p. D13).  
18, 19. Ventral and lateral views of specimen, USNM 163622 from locality K9-K112 to -120. Dhurma Formation, upper part, Atash Member.  
20, 21. Lateral and ventral views of specimen, USNM 163621 from Aramco locality L-916A. Tuwayq Mountain Limestone, near base.

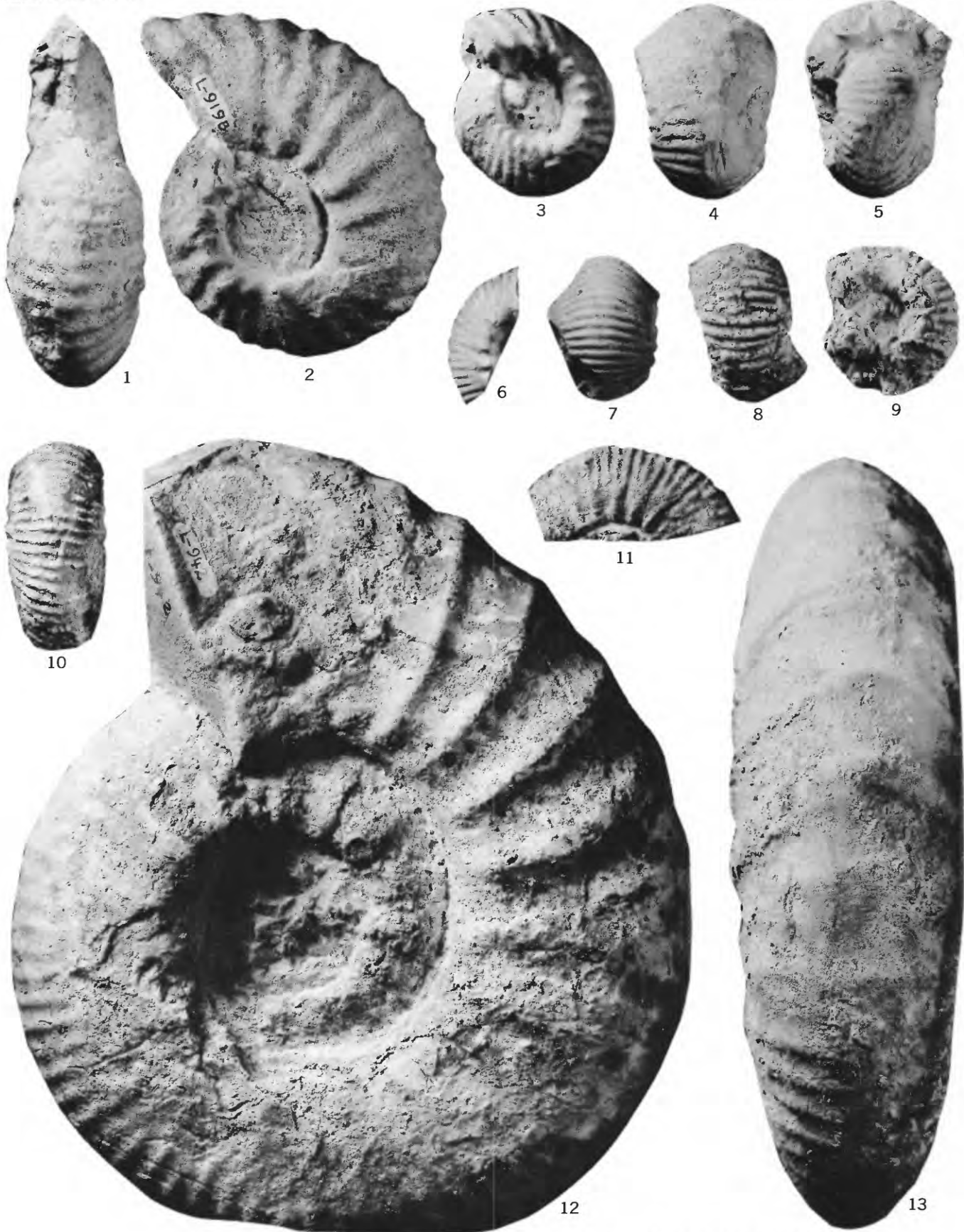


*SPIROCERAS, NORMANNITES?, DHRUMAITES, ROLLIERITES?, AND PACHYCERAS*

## PLATE 2

[All figures are natural size]

- FIGURES 1, 2. *Erymnoceras* (*Pachyerymnoceras*) cf. *E. (P.) jarryi* (R. Douvillé) (p. D13).  
Ventral and lateral views of specimen, USNM 163620 from Aramco locality L-919B. Dhruma Formation, near top of upper part.
- 3-9. *Erymnoceras philbyi* Arkell (p. D12)  
3-5. Lateral, ventral, and apertural views of hypotype, USNM 163616 from Aramco locality L-919A. Dhruma Formation, near top of upper part.  
6, 7. Lateral and ventral views of hypotype, USNM 163617 from Aramco locality L-929. Dhruma Formation, probably upper part.  
8, 9. Ventral and lateral views of hypotype, USNM 163615 from locality KK9-120.5. Dhruma Formation, upper part, Atash Member.
- 10, 11. *Erymnoceras* (*Erymnocerites*) sp. (p. D13).  
Ventral and lateral views of specimen, USNM 163619 from locality KK9-119.5. Dhruma Formation, upper part, Atash Member.
- 12, 13. *Erymnoceras* cf. *E. philbyi* Arkell (p. D12).  
Lateral and ventral views of adult specimen, USNM 163618 from Aramco locality L-942. Dhruma Formation, at top.



*ERYMNOCERAS*, *E.* (*PACHYERYMNOCERAS*), AND *E.* (*ERYMNOCERITES*)

### PLATE 3

[All figures are natural or nearly natural size unless otherwise indicated on plate]

FIGURES 1-4. *Grossouvria* sp. (p. D14).

1, 2. Ventral and lateral views showing lateral lappet of specimen, USNM 163625 from locality KK9-117. Dhruma Formation, upper part, Atash Member.

3, 4. Lateral and ventral views of septate specimen, USNM 163624 from locality KK9-112. Dhruma Formation, upper part, Atash Member.

5, 8. *Dhrumaites cardioceratoides* Arkell (p. D11).

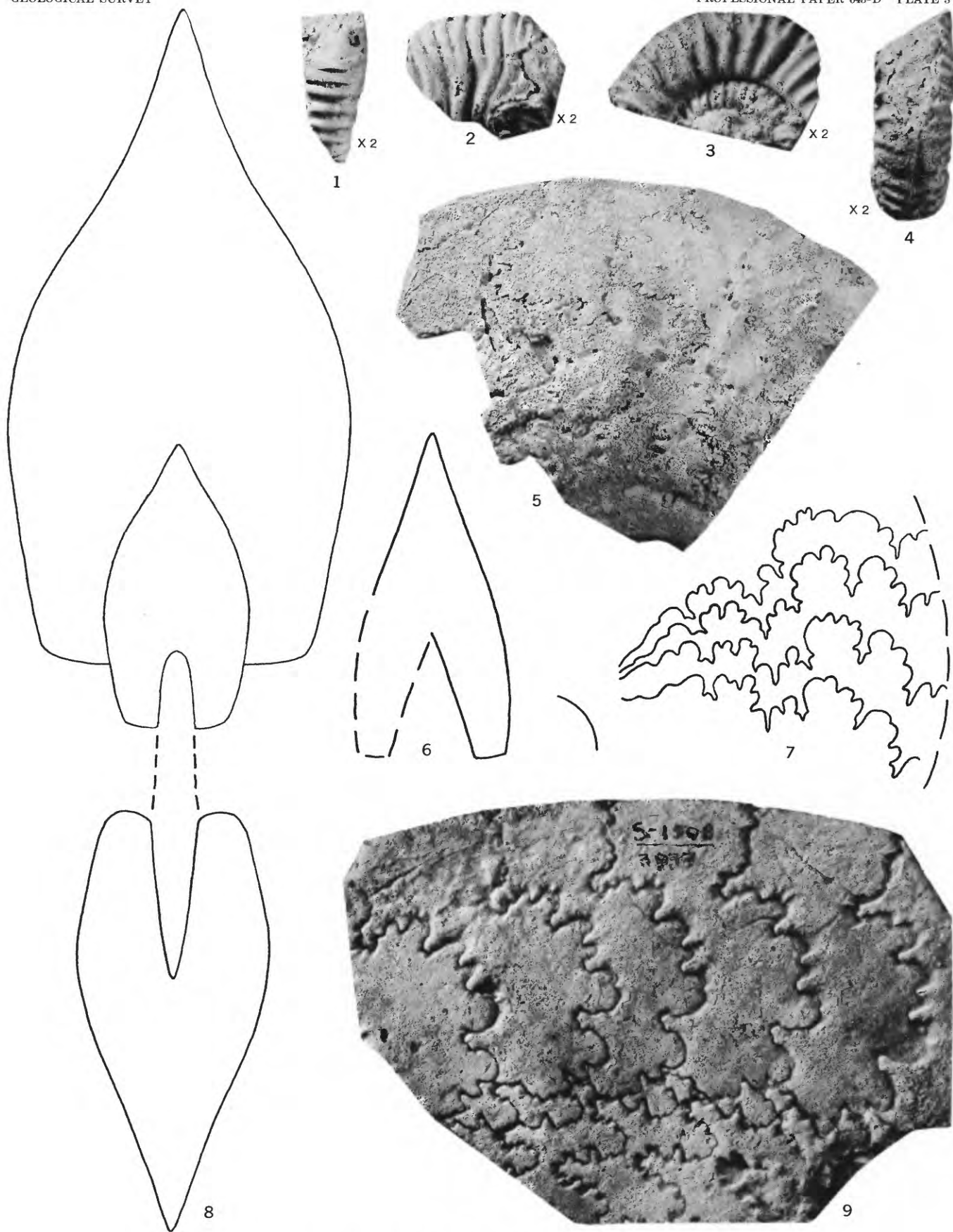
5. Apical end of large septate whorl (see pl. 4) lighted to emphasize the presence of faint broad flexuous ribs. Hypotype, USNM 163612 from locality KK9-73. Dhruma Formation, near top of middle part.

8. Cross-section of same large specimen.

6, 7, 9. *Dhrumaites* sp. (p. D12).

6, 7. Cross section and suture lines of fragment, USNM 163613 from locality KK8-6. Dhruma Formation, near base of middle part.

9. Found with holotype of *D. cardioceratoides* Arkell but differs by having broader saddles as in specimen shown herein on plate 4. Specimen, USNM 163614, from Aramco locality S-1508. Dhruma Formation, near top of middle part.



GROSSOUVRIA AND DHRUMAITES

## PLATE 4

[Figure about three-fourths natural size]

FIGURE 1. *Dhrumaïtes cardioceratoides* Arkell (p. D11).

Lateral view of large septate specimen, hypotype USNM 163612 from locality KK9-73. Other figures of same specimen shown on pl. 1, figs. 13-15 and pl. 3, figs. 5, 8. Dhruma Formation, near top of middle part.





*DHRUMAITES*