Late Paleozoic Stratigraphy of Central Cochise County Arizona

GEOLOGICAL SURVEY PROFESSIONAL PAPER 266

Late Paleozoic Stratigraphy of Central Cochise County Arizona

By JAMES GILLULY, JOHN R. COOPER, *and* JAMES STEELE WILLIAMS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 266

A report giving detailed descriptions of rocks of Mississippian, Pennsylvanian, and Permian ages, with representative sections and faunal lists of the formations concerned

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1954

UNITED STATES DEPARTMENT OF THE INTERIOR

Douglas McKay, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 45 cents (paper cover)

CONTENTS

ILLUSTRATIONS

LATE PALEOZOIC STRATIGRAPHY OF CENTRAL COCHISE COUNTY, ARIZONA

By JAMES GILLULY, JOHN R. COOPER, and JAMES STEELE WILLIAMS

ABSTRACT

In earlier work in central Cochise County, Ariz., the rocks above the Martin limestone (Devonian) were separated into two formations: the Escabrosa limestone (lower Mississippian) and the Naco limestone (Pennsylvanian). Thirty miles to the east, in the Chiricahua Mountains, the Paradise formation of late Mississippian age has been recognized.

In the area here considered—the northern Mule Mountains, Tombstone Hills, Dragoon Mountains, and Little Dragoon Mountains—the Escabrosa limestone is well developed; a limestone called the Black Prince limestone, probably referable to the upper Mississippian, is present; and the rocks formerly referred to the Naco limestone are subdivided into six formations. The Naco is a group that includes, from the base upward, the Horquilla limestone (Pennsylvanian), the Earp formation (late Pennsylvanian and possibly Permian), the Colina limestone (Permian? and Permian), and the Epitaph dolomite, the Scherrer formation, and the Concha limestone (all three of Permian age).

Representative stratigraphic sections, faunal lists, and age discussions of these units are included.

INTRODUCTION

The area of this investigation is shown in figure 1. Field work in the Pearce and Benson quadrangles was begun by Gilluly in 1936, and continued for four field seasons. He was assisted at various times by Edgar Bowles, R. S. Cannon, Jr., J. H. Wiese, W. B. Myers, F. S. Simons, and S. C. Creasey. Williams visited the field in 1938 and spent several days assisting in interpreting the stratigraphic succession in this much-faulted area. In 1944 Cooper began work in the Dragoon quadrangle just to the north and continued this work through 1949, assisted at various times by T. W. Amsden, F. W. Farwell, Kuo Wen Kuei, F. G. Bonorino, A. E. Disbrow, L. T. Silver, and C. T. Wrucke. Amsden in particular, did much work on the stratigraphy. In September 1947 the three authors spent about a week in field review of the stratigraphy.

Some of the fossils were originally studied by G. H. Girty, and his reports (both published and unpublished) have been drawn upon freely for the present report. These have been restudied by Williams, and the identifications have been revised to conform with current nomenclature. Williams has studied all the later collections also. Helen Duncan of the Geological Survey has identified the corals and bryozoans and has contributed remarks on these faunal elements. J. Brookes Knight of the National Museum has done the same for the gastropods, A. K. Miller of the University of Iowa for the cephalopods, J. Marvin Weller of the University of Chicago for the trilobites, and Edwin Kirk of the Geological Survey for the crinoids. Lloyd G. Henbest of the Geological Survey has identified the fusulinids and supplied comments on their significance. Williams has assembled the paleontologic data and is responsible for the age discussions and assignments here presented.

Throughout this report collections from representative stratigraphic sections described herein are given in order from top to bottom of formations. The fossils were identified in 1947, except for a few in 1948, and the terminology used is of that date. The various classes of fossils listed were identified by the respective persons just mentioned, and Williams has identified the brachiopods and other forms not credited to others. Collection numbers are those of the U. S. Geological Survey, and localities and zones at which these collections were made are shown in the stratigraphic sections or described in the registers of collections for the Escabrosa limestone, the Black Prince limestone, and the Naco group. Collection numbers preceded by this symbol ☆ (open star) are not from the measured stratigraphic sections presented but are from areas so near that the collections can be fitted into the sections with reasonable accuracy.

The maps of figures 1, 2, and 3 are presented to show the general areal relations of the sections described. Their scale is inadequate to show all the geographic positions referred to in the text but these may all be found on the topographic maps of the Pearce, Benson, and Dragoon quadrangles published by the Geological Survey.

PRIOR WORK

F. L. Ransome, who established the Escabrosa and Naco limestones as formations in the Bisbee district, just to the south of this area (1904), also mapped the Tombstone mining district (1920) and the Turquoise district near the southeast flank of the Dragoon Mountains (1913). At Tombstone he recognized the Escabrosa and Naco limestones. Both at Bisbee and Tombstone, the fauna of the Naco limestone was divisible into an earlier Pennsylvania part, roughly equivalent to that of the "Magdalena limestone of New Mexico,"

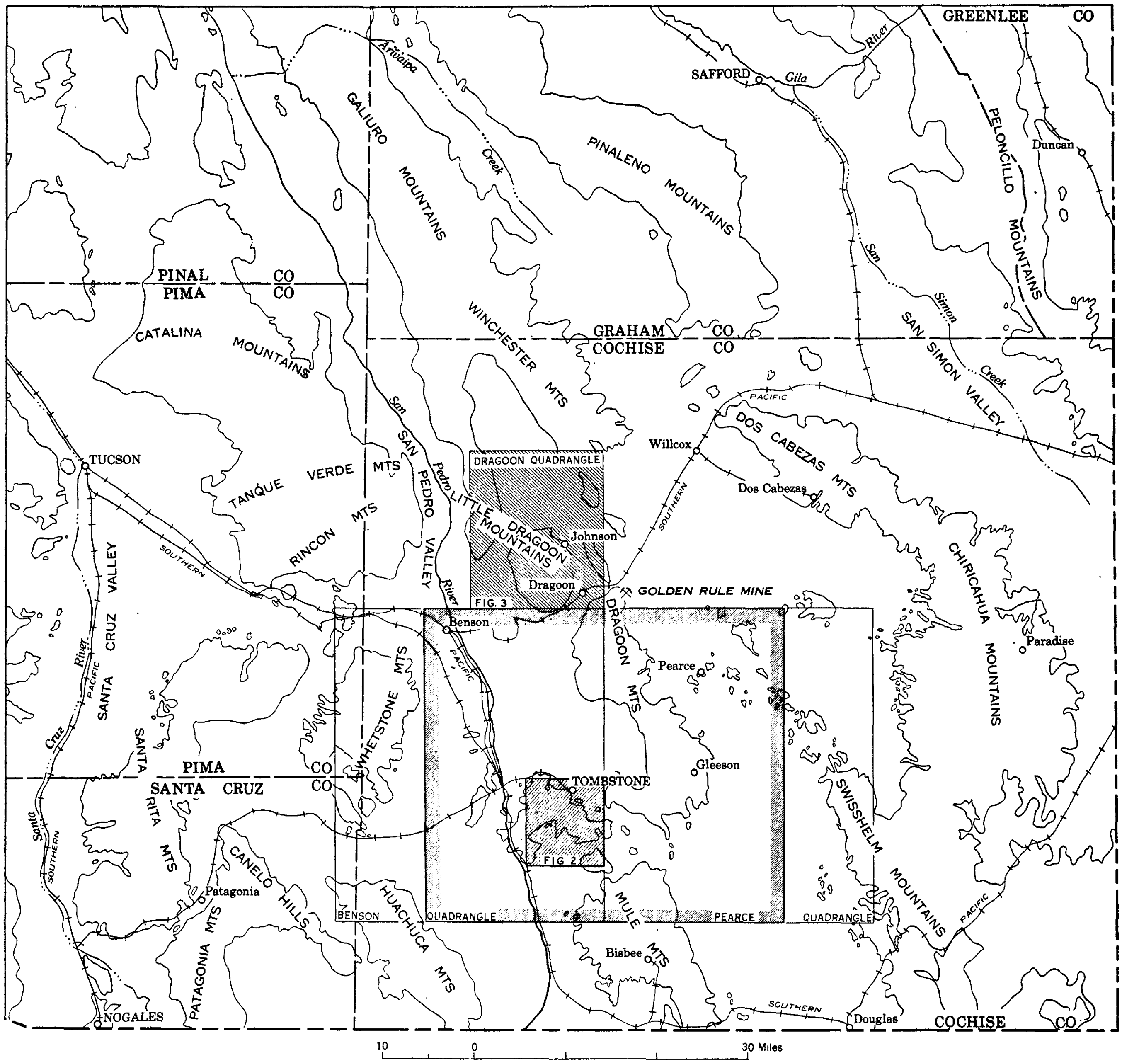

FIGURE 1.—Index map of southeastern Arizona showing the area within which stratigraphic studies were made.

and a later Pennsylvanian part that was compared with the middle or upper Hueco or Manzano of New Mexico (Girty, 1916, p. 148–149). Although these subdivisions were not mapped by Ransome, there is no doubt that he recognized the corresponding stratigraphic distinctions, for several faults he mapped at Tombstone are identifiable only on stratigraphic grounds. Ransome's work in the Turquoise district was hasty reconnaissance and he made no attempt to subdivide the upper Paleozoic rocks. Wilson (1927) recognized the presence of both Mississippian and Pennsylvanian rocks in the Courtland-Gleeson area, but did not map them separately. Darton (1925) in hasty reconnaissance also identified, but did not map the Escabrosa and Naco limestones. Stoyanow (1936) recognized rocks of Permian age in the Little Dragoon Mountains.

MISSISSIPPIAN ROCKS

ESCABROSA LIMESTONE

DISTRIBUTION AND GENERAL CHARACTER

The Escabrosa limestone crops out in the northwestern Mule Mountains (fig. 1), in the Tombstone Hills, in many small fault blocks in the southeastern end of the Dragoon Mountains, and along the main

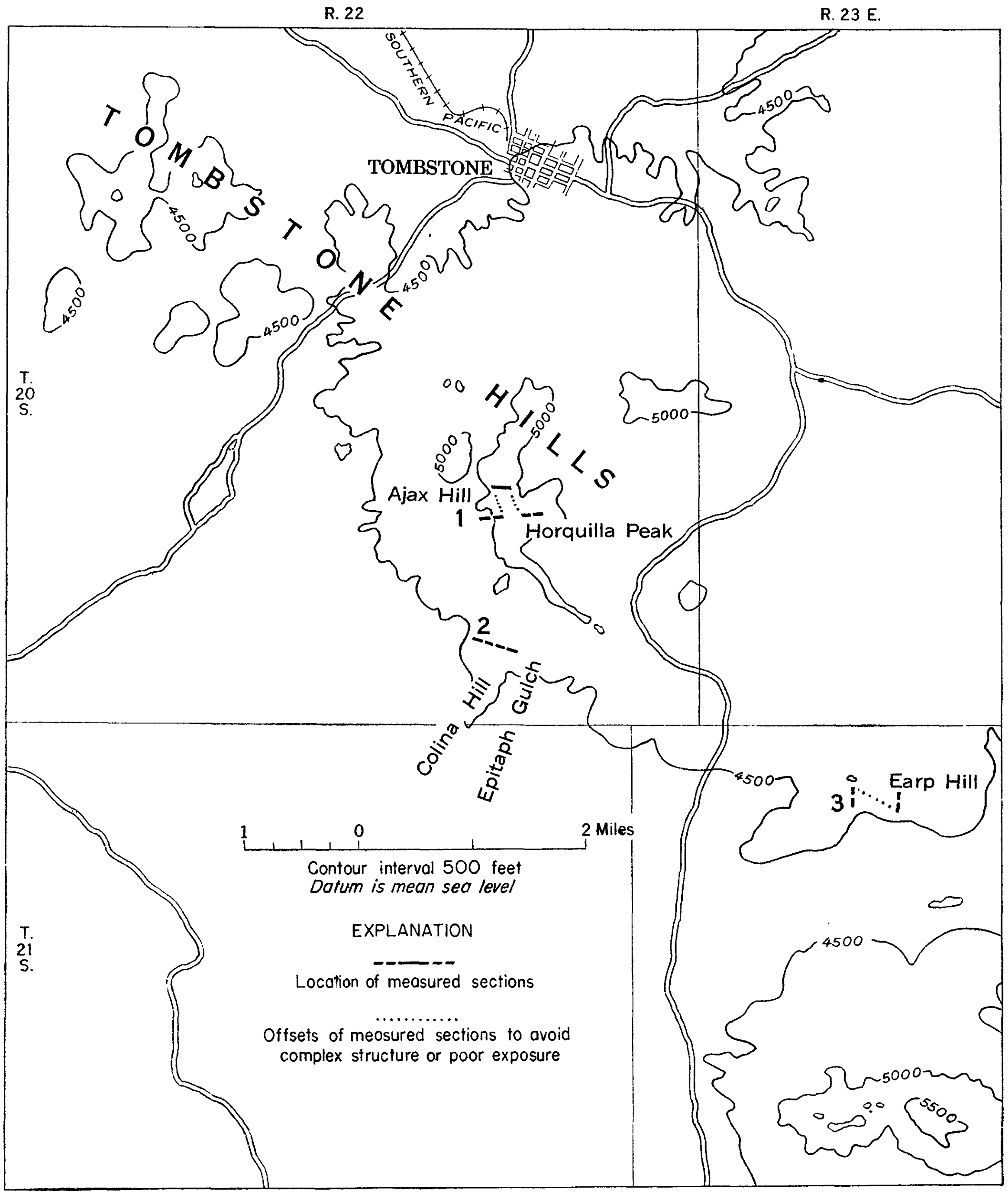

FIGURE 2.—Map showing location of measured stratigraphic sections in the Tombstone Hills, Cochise County, Arizona.

ridge of the Dragoon Mountains west of Pearce. It is also found in many parts of the Little Dragoon Mountains, in the Gunnison Hills, and in the Johnny Lyon Hills.

In all these localities, most of which are shown in figures 2 and 3, the Escabrosa limestone forms prominent ridges and bold outcrops. The lower, more massive part, in particular, crops out in impressive cliffs. The upper part is more thinly bedded and less conspicuous in outcrop.

STRATIGRAPHY

The base of the Escabrosa limestone is generally not well-exposed because of the accumulation of talus on the gentler slopes of the underlying Martin limestone, a much less resistant formation. Generally, above this talus the massive part of the Escabrosa is nearly barren and even the thinner beds near the top are well-exposed on dip slopes.

As pointed out by Ransome, the characteristic rocks of the Escabrosa, both at Bisbee and in the Tombstone

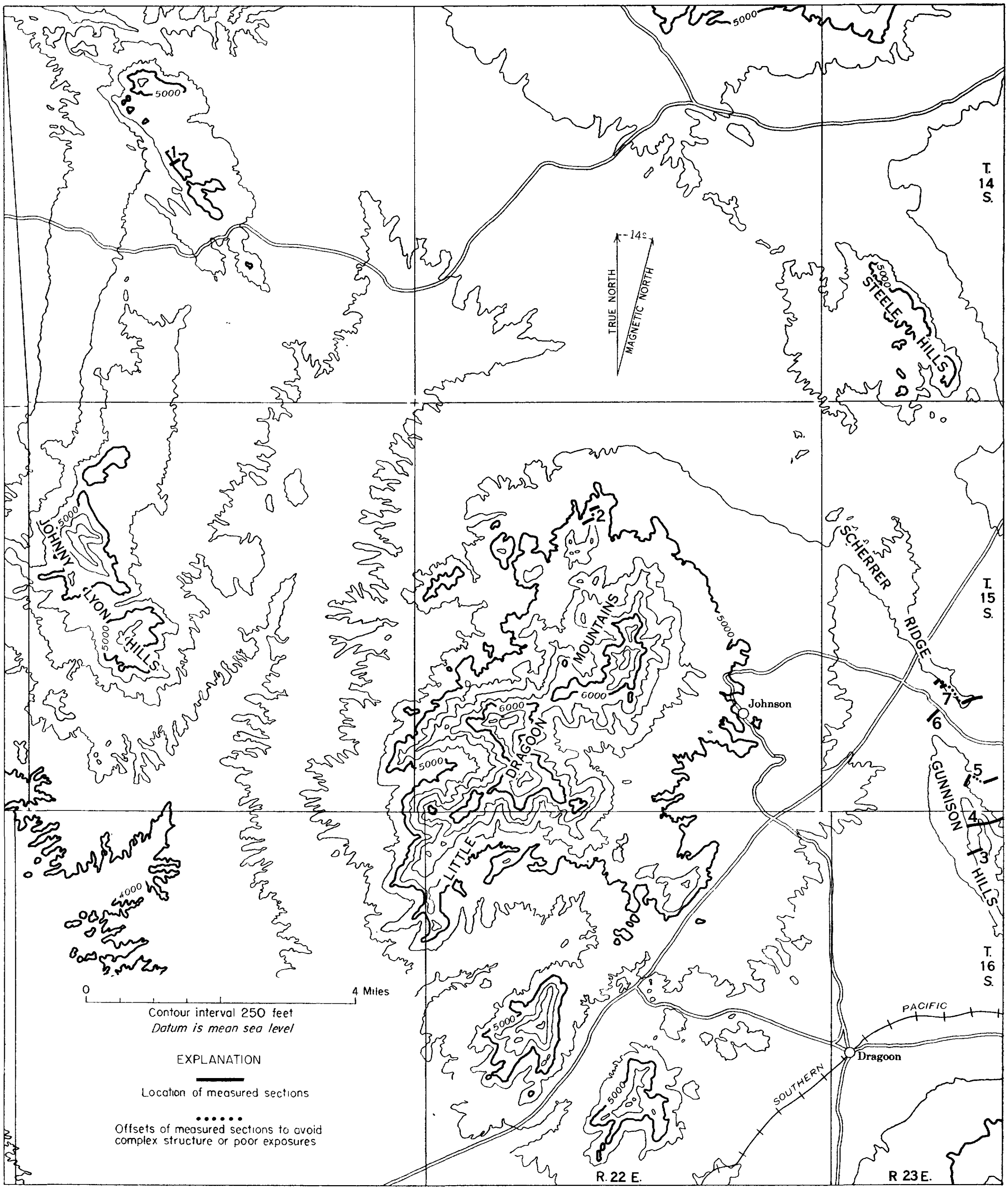

FIGURE 3.—Map showing location of measured stratigraphic sections in the Dragoon quadrangle, Cochise County, Arizona.

Hills, are white to light-gray, coarse, granular limestones, commonly composed largely of fragments of crinoid stems. Most parts are thick bedded. In the lower part, beds 10 to 20 feet thick are conspicuous, and though the beds are somewhat thinner in the upper part, they form practically an unbroken slope to within a few score feet of the top. There are a few beds of finely crystalline, dark gray limestone in the lower part of the formation, but this variety of rock is subordinate except near the top. These fine-grained rocks are generally gray on fresh fracture, in contrast to the slightly pinkish tints of the overlying Black Prince and Horquilla limestones. Because a few beds of fine-grained limestone that are pink on fresh fracture are found near the top of the Escabrosa as mapped in the Tombstone Hills and Dragoon Mountains, the boundary with the limestones of the Horquilla is generally difficult to recognize. As will appear in the later discussion, it is possible that these thin beds may be equivalent to part of the Paradise formation of the Chiricahua Mountains, though they do not resemble that formation lithologically, as it is described by Stoyanow (1926, 1936) and Hernon (1935). It is more likely that the thin upper beds are in part equivalent to the Black Prince limestone of the Little Dragoon Mountains, Gunnison Hills, and Johnny Lyon Hills (see p. 14), but in absence of a clastic basal member such as is present in that formation, field discrimination of a contact was not feasible.

Neither sandstone nor shale has been found in the Escabrosa limestone. Chert is absent in the lower part but a few thin, fairly continuous bands occur in the middle and nodular chert is common in the upper part. In the Bisbee area Ransome (1904, p. 43) described the Escabrosa as essentially free from dolomite. Field tests with dilute acid have shown considerable dolomite in the lower, massive part of the formation everywhere in the area of this report except the Mule Mountains, though the formation is dominantly calcitic.

As mentioned above and by Ransome, the contact of the Escabrosa limestone with the overlying Naco group is not readily detected from lithology. In unfaulted sections in the Bisbee district and in the Tombstone Hills, where the fossil content of the beds has been carefully considered, the boundary between Mississippian and Pennsylvanian faunal zones comes in the first weak zone above the cliff-forming part of the Escabrosa. This is true on Military Hill and a half-mile southeast of Ajax Hill in the Tombstone area and north of Don Luis in the Bisbee quadrangle, as determined by Williams. In the much faulted areas of the Dragoon Mountains and in the Courtland-Gleeson area it is generally impractical to make a paleontological division, and there is little doubt that in these areas the thin-bedded parts of the formation have locally been mapped as parts of the Horquilla limestone, which they so closely resemble.

Farther north, in the Little Dragoon Mountains, Gunnison Hills, and Johnny Lyon Hills, about 150 feet of transitional beds between the Escabrosa limestone and the Naco group have been mapped as the Black Prince limestone. Though relatively low in chert, the Black Prince limestone is difficult to distinguish from the adjacent formations by lithology alone. It is separable in mapping because it has a weak basal member of shale and conglomerate, and there is a similar clastic member at the base of the overlying Horquilla limestone as defined. Of the two weak zones, the one at the base of the Horquilla limestone generally forms the more conspicuous topographic sags and saddles. The Black Prince limestone is less fossiliferous than either of the adjacent formations.

The only fossils found in the lower part of the Escabrosa limestone are the crinoidal fragments of which the rock is so largely composed, a few corals, and a single specimen of bryozoan. Some cup corals in the lower Escabrosa are more than 18 inches long—much longer than any seen in the rocks of the Naco group. Higher in the formation brachiopods and other fossils are relatively much more abundant.

THICKNESS

In the Tombstone Hillls, the Escabrosa limestone is 733 feet thick, whereas it was measured by Ransome (1916, p. 147) as 600 to 800 feet in the Bisbee area. In the Dragoon Mountains faulting is so prevalent that there is no possibility of measuring the formation except, perhaps, near the Golden Rule mine, near the northeast corner of the range, where it is about 750 feet thick, though bedding-faulting at the base prevents assurance that the section is complete. In the Gunnison Hills the formation is 755 feet thick, in the Little Dragoon Mountains 585 feet thick, and in the northern Johnny Lyon Hills 594 feet thick. The thicknesses given for these three northern sections do not include the Black Prince limestone which is recognized there. The measurements in the Little Dragoon Mountains and Johnny Lyon Hills are significantly less than the others made during this study and suggest either that there has been a moderate thinning of the formation in the northwestern part of the area considered, or that the southern sections include strata that are equivalent to the Black Prince limestone, a correlation permitted but not demanded by faunal analysis.

REPRESENTATIVE SECTIONS

The following sections are considered representative of the Escabrosa as developed in this area. They are shown graphically in figure 4.

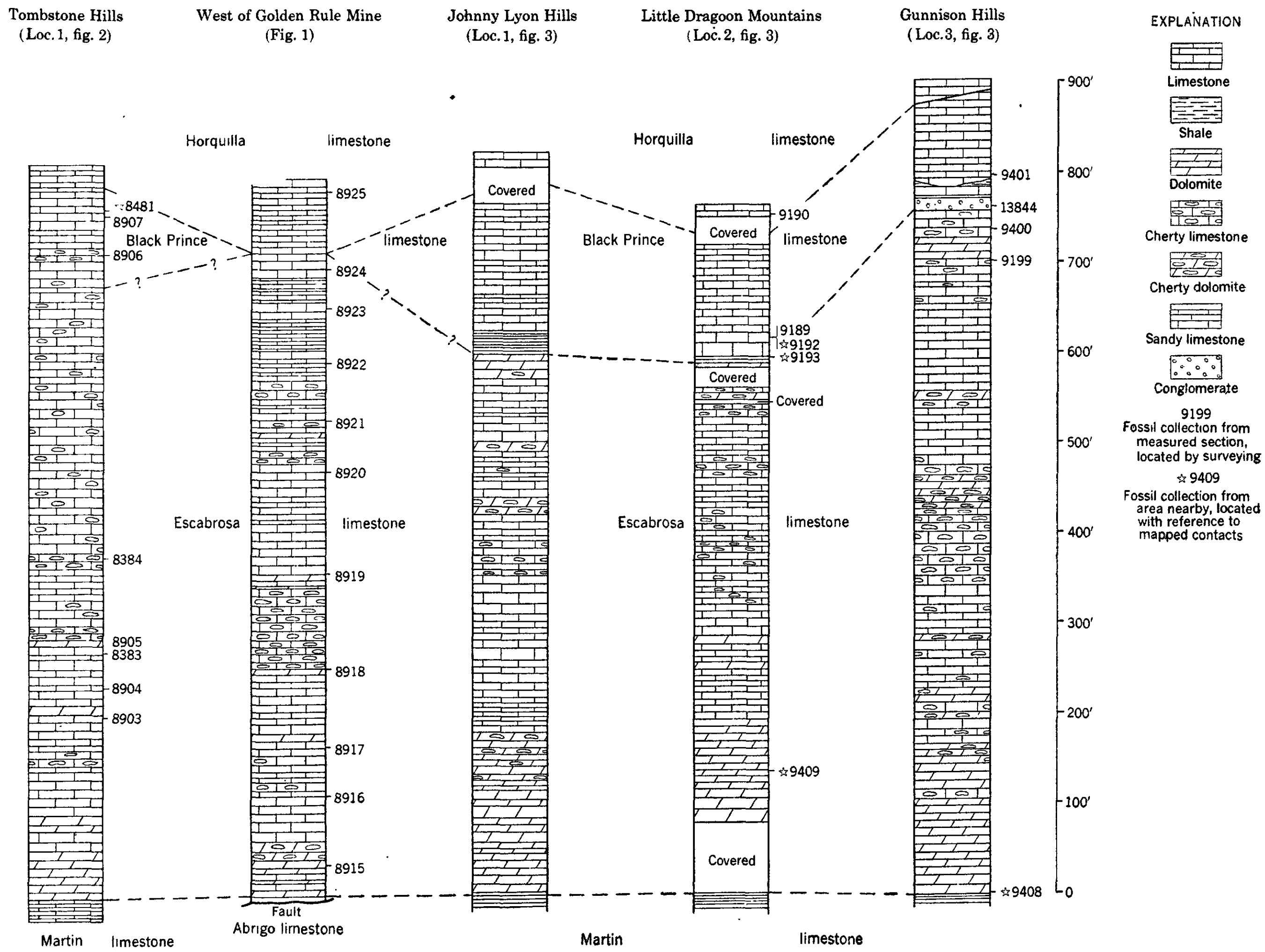

FIGURE 4.—Sections of formations of Mississippian age, Cochise County, Arizona.

Section of Escabrosa limestone in Tombstone Hills. (Units 1 and 2 measured half a mile southeast of Ajax Hill; others east of Ajax Hill.)

	Thickness (feet)
Horquilla limestone:	
Limestone, thin-bedded, blue-gray, slightly pink on fresh fracture, fossiliferous. Member 19, page 17.	
Escabrosa limestone:	
1. Limestone, dense, pink cast on fresh fracture; considerable chert, appearing like breccia near base. Beds range from 2 to 20 in. in thickness, averaging 6 in. Forms a dip slope. (Coll. 8907, about 50 ft below top)	79
2. Limestone, gray, with a faint pink cast on fresh fracture, in beds 6–18 in. thick, much concretionary chert in thin nodules along bedding. Forms a steep cliff. (Coll. 8906, about 20 ft below top)	313
3. Limestone, dark blue-gray, same on fresh fracture, in beds 6–12 in. thick, a little nodular chert at the base, with more evenly layered thin (2–3 in.) chert beds near the top. Very fossiliferous toward the top (coll. 8384) and less fossiliferous toward base (colls. 8383 and 8905)	106

Section of Escabrosa limestone in Tombstone Hills, etc.—Con.

	Thickness (feet)
Escabrosa limestone—Continued	
4. Limestone, dark blue-gray, same on fresh fracture, resembles unit 5, except nondolomitic. A few thin sandy streaks, but thick bedded. (Coll. 8904)	30
5. Dolomite, dark blue-gray, massive, grades upward into unit 4	8
6. Limestone, blue-gray, massive above, but in 2-in. beds toward the base. A thin zone of ripple-marked, sandy limestone and edgewise conglomerate at the base. (Coll. 8903)	72
7. Limestone, blue-gray, massive, granular, in a thick bed	8
8. Limestone, gray, massive, granular in beds about 3 ft thick, with indistinct partings. A few thin layers of rusty-weathering chert. Many cup corals	20
9. Dolomite, gray, massive, crinoidal; discontinuous chert layers 2 in. or less in thickness, commence about 10 ft above base and occur at intervals to top. Resembles unit 8 very closely	19
10. Limestone, light-gray, coarsely granular, massive, closely resembles underlying unit	23

Section of Escabrosa limestone in Tombstone Hills, etc.—Con.

	Thickness (feet)
Escabrosa limestone—Continued	
11. Dolomite, gray to blue, chiefly gray, very massive, largely crinoidal, weathers with notably pitted surface, fossiliferous but difficult to extract	55
Total thickness of Escabrosa limestone	733
Martin limestone:	
Limestone, blue-gray, poorly exposed	15±

Although it is believed that essentially the same bed was followed in piecing together this offset section, an overall measurement of the Escabrosa limestone half a mile southeast of Ajax Hill gave a thickness of 786 feet. The difference is within the limits of error of measurement and is not considered to indicate notable lensing.

Section of Escabrosa limestone in hill west of Golden Rule mine in northeast spur of Dragoon Mountains

Horquilla limestone:
Limestone, chiefly medium-grained, crinoidal, with subordinate light-gray, fine-grained beds; pink cast on fresh fracture, weathering medium to light gray; average bed about 3 ft, ranging from 8 in. to 6 ft.
Conformable contact.

	Thickness (feet)
Escabrosa limestone:	
1. Limestone, beds 2–4 in., locally dolomitic, with lenticles of brown-weathering chert. A few 3-ft ledges of massive, dark-gray limestone. Forms smooth slope, broken by low ledges, but along strike forms steep cliff. (Coll. 8924 about 16 ft below top)	54
2. Limestone, light-gray, varying from coarsely crinoidal to dense; massive, forms strong ledge. (Coll. 8923 about middle of unit)	19
3. Limestone, blue-gray, finely crystalline to dense, with many crinoid fragments; beds average less than 1 ft thick, but with a few 3–6 ft massive ledges of limestone with subordinate chert. Gray on fresh fracture but weathering slightly pink	51
4. Limestone, blue-gray, massive, forms ledge. (Coll. 8922, at top)	5
5. Limestone, generally fine-grained, but with some coarse, crinoidal layers, bedding 6 in.–1 ft thick; light gray on fresh fracture, weathering gray with pink cast	10
6. Limestone, massive, contains irregularly-branching chert nodules; forms strong ledge	20
7. Limestone, beds 6 in. to 2 ft, some pink, dense, weathering light pinkish gray; some coarsely crinoidal, weathering light gray. Sporadic lenticular cherts as much as 2 in. thick. Forms gentle slope broken by low ledges. (Coll. 8921, at 15 ft above base)	58
8. Limestone dolomitic, dense, light-gray, weathering yellowish on upper surface; forms ledge	2½
9. Limestone, gray, thin-bedded, poorly exposed	4
10. Limestone, pinkish, dense, slightly dolomitic toward top; forms strong ledge	5

Section of Escabrosa limestone in hill west of Golden Rule mine in northeast spur of Dragoon Mountains—Continued

	Thickness (feet)
Escabrosa limestone—Continued	
11. Limestone, dense, weathers very dark gray, bedding averages about 8 in.; many short chert lenses. (Coll. 8920, at base)	15½
12. Limestone, dark-gray, finely crystalline, with 3 or 4 thin, continuous bands of chert; forms strong ledge	7
13. Limestone, medium-gray to pinkish-gray on fresh fracture, weathering to dull gray; chiefly finely crystalline, with sporadic coarse, crinoidal beds; beds range from 2–4 ft; forms slope broken by low ledges	104
14. Limestone, dolomitic, dark-gray, very finely crystalline; in beds 2–8 in. thick, weathering to platy fragments	15
15. Limestone, massive, crinoidal, with lenticular chert nodules; a single conspicuous ledge. (Coll. 8919, at top)	3
Possible fault.	
16. Limestone, irregularly mottled with buff dolomitic beds about 6 in. thick; chiefly finely crystalline with faint pink cast on fresh fracture, weathering medium gray to almost black; a few coarse crinoidal beds; a little black and brown chert in fairly continuous thin layers; thinner bedded toward the top. (Coll. 8918, at base)	106
17. Dolomite, finely crystalline; pinkish-gray on fresh fracture; weathers buff gray	3
18. Limestone, dense, light-pinkish gray on fresh fracture, weathering medium gray; bedding ranges from 2 in. to 3 ft; average about 8 in.	45
19. Limestone, dense to coarsely crystalline, crinoidal, weathers medium gray, with locally a slight purplish cast; a few beds of buff dolomite near middle of unit; indistinct bedding, averages about 1 ft	15
20. Limestone, dark- to light-gray on fresh fracture, weathering light gray, interbedded with sporadic thin beds of dense, brown-weathering dolomite and discontinuous sandy limestone. (Coll. 8917, at base)	15
21. Limestone, sandy, poorly exposed, weathering to thin chips except for a single 4 ft. massive ledge	48
22. Limestone, light pinkish-gray to light-gray on fresh fracture, weathers gray with a faint pinkish cast, varying to blue-gray; contains chert nodules ½–2 in. thick, contorted	10
23. Limestone, poorly exposed, thin-bedded (8 in.), medium- to dark-gray on fresh fracture, weathering gray to buff. (Coll. 8916, at top)	50
24. Dolomite, massive, finely crystalline, light-gray to medium-gray on fresh fracture, weathering dark gray to black; mottled with sporadic nodules of white and orange chert	30
25. Dolomite and limestone in beds about 2 ft thick, somewhat brecciated. (Coll. 8915, at top)	34
Total exposed Escabrosa limestone	729

Fault contact (Martin limestone faulted out).
Abrigo limestone.

Section of Escabrosa limestone in west slope of main peak of Gunnison Hills (NE¼SW¼ Sec. 4, T. 16 S., R. 23 E.)

	Thickness (feet)
Black Prince limestone:	
Shale, deep-maroon, with light-green mottling; contains scattered nodules of chert and one 6-in. bed of sedimentary breccia with chert fragments as much as 1 in. in diameter. Unit 2, page 14.	
Escabrosa limestone:	
1. Limestone, pinkish-gray, with chert nodules; beds 1 to 3 ft thick. (Coll. 9400, 15 ft below top)	31
2. Dolomite, silty, black but weathering tannish red, with chert in small nodules; a few limestone beds present; beds 6 to 12 in. thick, some slightly shaly	22
3. Limestone, light-gray, with irregular lenses of dolomite and chert nodules. (Coll. 9199, from top 5 ft)	64
4. Limestone, light gray, in part crinoidal, essentially free from chert; beds 3 to 5 ft thick	82
5. Dolomite, light-gray, with many white chert nodules; beds 1 to 2 ft thick	11
6. Limestone, light-gray, with many chert nodules: beds 1 to 3 ft thick	8
7. Limestone, white but weathering mottled blue-gray, essentially free from chert, beds 3 to 5 ft thick. Forms cliff	49
8. Limestone, light blue-gray, with nodules and lenses of brown-weathering chert; beds 2 to 3 ft thick	26
9. Dolomite, light-gray, fine-grained, with much brown-weathering chert in elongate nodules and lenticular beds as much as 6 in. thick; dolomite beds 1 to 2 ft thick	36
10. Limestone, light-gray, with chert nodules as much as 1 ft thick and several feet long; chert nodules, which are much more abundant and larger than in underlying members, light-gray on fresh fracture but brown on weathered surface; limestone beds 2 to 5 ft thick. Forms steep slope	87
11. Limestone, light-gray, mostly fine-grained, with scarce small (about 1 in. thick and several inches long) chert nodules; beds 1 to 4 ft thick	53
12. Dolomite, light-gray, with scarce small chert nodules; beds 1 to 3 ft thick	6
13. Limestone, similar to unit 11	53
14. Dolomite, similar to unit 12	16
15. Limestone, similar to unit 11 except darker gray	12
16. Dolomite, similar to unit 12	6
17. Limestone, light-gray, weathering to satiny surface, with a few chert nodules; beds 2 to 4 ft thick	27
18. Dolomite, light blue-gray, weathering to slightly pitted surface, with brown chert nodules in upper part	50
19. Limestone, weathering to satiny surface, with irregular chert nodules at top; similar to unit 17	10
20. Dolomite, light-gray, weathering to granular pitted surface; beds 2 to 3 ft thick	40

Section of Escabrosa limestone in west slope of main peak of Gunnison Hills—Continued

	Thickness (feet)
Escabrosa limestone—Continued	
21. Dolomite, light-gray, fine-grained, weathering to smooth surface; basal contact gradational over 2 to 4 ft and lower several feet of dolomite is reddish tan	66
Thickness of Escabrosa limestone	755
Martin limestone:	
Shale; reddish-gray, fissile.	

Section of Escabrosa limestone in Little Dragoon Mountains, 3½ miles northwest of Johnson (SE ¼ sec. 9, T. 15 S., R. 22 E.)

	Thickness (feet)
Black Prince limestone:	
Covered except for one small out crop of red shale; much float of fossiliferous limestone. Unit 2, page 14.	
Escabrosa limestone:	
1. Dolomite, gray, weathered surface brownish gray with rusty red spots, fine-grained	3
2. Covered	24
3. Limestone, gray, crinoidal, with chert nodules	2
4. Covered	4
5. Dolomite, dark-gray, weathered surface light creamy gray, fine-grained, with brown chert nodules; somewhat more calcareous in upper part	7
Section offset about 600 feet south across small fault; error involved in offset probably less than 10 feet.	
6. Covered	6
7. Limestone, light gray, with nodules coated by chert (weather brown)	14
8. Limestone, light-gray, with chert nodules in lower 25 ft; beds 1 to 3 ft thick	65
9. Limestone, similar to member 8 but darker and essentially free from chert	35
10. Limestone, gray, medium- to fine-grained, with many irregular chert nodules; beds 1 to 3 ft thick	29
11. Limestone, gray, fine-grained to aphanitic in layers 2 to 6 in. thick, alternating with chert layers weathering deep reddish brown	17
12. Limestone, gray, with brown nodules and lenses (as much as 5 ft long) of chert; beds 1 to 3 ft thick	59
13. Limestone, weathered surface dark gray and granular; 6-in. flat pebble conglomerate at base; beds 1 to 4 ft thick	27
14. Limestone, light-gray, fine-grained, weathering to satiny pitted surface; single bed	10
15. Dolomite, nearly black, weathered surface dark gray, fine-grained	8
16. Limestone, similar to unit 14, in 1- to 4-ft beds	23
17. Dolomite, gray, medium-grained, weathered surface granular	4
18. Limestone, similar to unit 14, in 6-in. to 4-ft beds	27
19. Limestone, dark-gray to reddish-gray, dense, fine-grained, thin-bedded (6 to 18 in.)	16
20. Limestone, similar to unit 14, single bed	13
21. Dolomite, black, fine-grained, with many thin veins of calcite	2
22. Dolomite, gray, fine-grained, weathering to smooth surface	23

Section of Escabrosa limestone in Little Dragoon Mountains, 3½ miles northwest of Johnson—Continued

	Thickness (feet)
Escabrosa limestone—Continued	
23. Limestone, blue-gray, dense, fine-grained; single bed	9
24. Dolomite, weathering dark gray, medium-grained weathered surface pitted; upper part sheared	65
25. Dolomite, light-gray, weathered surface smooth; not very distinct from unit 24	15
26. Covered	78
Thickness of Escabrosa limestone	585
Martin limestone:	
Shale, reddish-brown, with 2½ ft of hard reddish-brown sandstone at top.	

The 78-foot covered interval at the bottom of the above section was assigned to the Escabrosa limestone because an apparently complete section of the Martin limestone occurs below it and because the 78 feet is required in the Escabrosa to make the cherty zones and other characteristic beds occurring higher in the formation match with several partial sections measured in the vicinity. Judging from these partial sections, the concealed beds probably consist of fine-grained dolomite at the base, overlain by medium-grained dolomite weathering to a granular pitted surface.

Section of Escabrosa limestone in northern part of Johnny Lyon Hills, (sec. 16, T. 14 S., R. 21 E.)

	Thickness (feet)
Black Prince limestone:	
Shale, red and purple, the latter variety containing rounded chert fragments. Partly covered. Unit 2, page 14	
Escabrosa limestone:	
1. Dolomite, light tannish-gray, with nodules of chert. Top 10 ft poorly exposed	26
2. Limestone, light-gray, with a few scattered nodules and lenses of chert	70
3. Dolomite, light-gray, fine-grained, with lenses and nodules of chert	9
4. Limestone, light-gray, with very scarce chert nodules; beds 2 to 3 ft thick	52
5. Dolomite, light-gray, fine-grained with much chert in bedded lenses and irregular pods. Chert nodules light-gray and blue-gray on fresh fracture, brown on weathered surface	18
6. Limestone, light-gray, with very little chert; beds a few inches to 2 ft thick	51
7. Limestone, light-gray, with abundant nodules and lenses of white to bluish chert; beds 1 to 2 ft thick. Forms crest of ridge, (higher beds measured on dip slope)	17
8. Limestone, light-gray, free from chert, thick-bedded. Forms cliff	51
9. Limestone, light blue-gray with a few dark-gray beds, fine-grained, in beds 2 to 12 in. thick; contains quartz geodes as much as 2 in. in diameter; one 2-ft bed carries disseminated sand grains; upper part slightly dolomitic and not well exposed	32

Section of Escabrosa limestone in northern part of Johnny Lyon Hills—Continued

	Thickness (feet)
Escabrosa limestone—Continued	
10. Limestone, light-gray, with slightly pinkish cast, essentially free from chert; beds as much as 12 ft thick; forms cliff	61
11. Limestone, light blue-gray, with pinkish cast on weathered surface, light-gray to nearly black on fresh fracture; fine-grained; lowest bed 4 to 5 ft thick, the rest 1 to 12 in. thick	29
12. Dolomite, light-gray, weathering to smooth surface, with quartz geodes as much as 6 in. in diameter and nodules and lenses of blue-black chert; one bed carries fine silt; beds 1 to 3 ft thick	55
13. Dolomite, dark-gray, weathering to pitted surface; contains small (1–2 in.) quartz geodes, corals, and fragments of crinoids; beds 2 to 6 ft thick	67
14. Dolomite, light-gray, weathering to smooth surface; contains small (1 in. or less) quartz geodes. Similar to unit 12 except geodes smaller and lacks chert; beds 1 to 3 ft thick	56
Total Escabrosa limestone	594
Martin limestone:	
Shale, red, calcareous, poorly exposed.	

FAUNA AND CORRELATION OF THE ESCABROSA LIMESTONE

By James Steele Williams

The Escabrosa fauna consists largely of brachiopods but one or more corals are present in nearly every collection made from the Escabrosa for this investigation. Several collections consist entirely or almost entirely of corals. Crinoid columnals are very common in the collections, but calices are rare. Gastropods and pelecypods are few and poorly preserved. Trilobites are also rare. No cephalopods were found.

Many of the collections are small, for they were made in incidental fashion during the mapping and the measuring of stratigraphic sections. Furthermore, because of other duties, the amount of time that the paleontologist could spend with the party was brief. The main purposes of making collections were: to help identify the formations where there were uncertainties, to verify the previously ascertained age of some of the formations, to see whether zones that would be of immediate value to field geologists could be readily established, and to find out whether beds younger than those previously identified occurred in the top.

COLLECTIONS FROM SECTION OF ESCABROSA LIMESTONE IN THE TOMBSTONE HILLS (SEE P. 6)

[Localities outside section described in register, p. 13]

Collection 8907. From zone about 50 feet below top of Escabrosa; unit 1 of stratigraphic section on p. 6.

Spirifer centronatus? Winchell

cf. *S. leidyi* Norwood and Pratten

"*Productus*"? sp. indet.

Collection ☆ 8481. From a zone nearby thought to be the same as unit 1 of stratigraphic section on p. 6.
Linoproductus altonensis (Norwood and Pratten)
gallatinensis (Girty)
sp. undet.

Collection 8906 (from unit 2 of stratigraphic section on p. 6).
Spirifer centronatus Winchell?
cf. *S. pellaensis* Weller
Linoproductus altonensis (Norwood and Pratten)?
gallatinensis (Girty)?
"*Productus*"? sp. indet.
Rhipidomella burlingtonensis (Hall)
Punctospirifer? sp. undet.
Dielasma? cf. *D. burlingtonensis* (White)
Pelecypods, 2 or 3 sp. undet.
Ameura? or a closely related trilobite

Collection 8384 (from unit 3 of stratigraphic section on p. 6).
Empodesma? sp.
Triplophyllites? sp. A
Spirifer centronatus Winchell
centronatus Winchell var. A
Brachythyris cf. *B. peculiaris* (Shumard)?
Dictyoclostus arcuatus (Hall)?
Rhipidomella thiemei (White)

Collection 8383 (from unit 3 of stratigraphic section on p. 6).
Rotiphyllum? sp.
Triplophyllites? sp. A
Spirifer centronatus Winchell
Chonetes sp. undet.

Collection 8905 (from unit 3 of stratigraphic section on p. 6).
Triplophyllites? sp. A
Fenestella sp. 2
Camarotoechia metallica (White)
Spirifer centronatus Winchell
S.? sp. indet.
Schuchertella? cf. *S. chemungensis* (Conrad)
Chonetes sp. indet.
Linoproductus gallatinensis (Girty)
"*Productus*"? sp. undet.
Rhipidomella thiemei (White)
Punctospirifer subtextus (White)
Reticulariina? sp. undet.
Pelecypods, 2 or 3 sp. undet.
Trilobite, 2 pygidia, "lower Mississippian type"

Collection 8904 (from unit 4 of stratigraphic section on page 6).
Zaphrentoid coral cf. *Empodesma*
Triplophyllites? sp. A
Caninoid coral, indet.
Punctospirifer? sp. undet.

Collection 8903 (from unit 6 of stratigraphic section on page 6).
Horn coral, gen. indet.

COLLECTIONS FROM STRATIGRAPHIC SECTION OF ESCABROSA LIMESTONE IN THE DRAGOON MOUNTAINS MEASURED ON HILL WEST OF GOLDEN RULE MINE, NORTHEAST SPUR OF DRAGOON MOUNTAINS.

Collection 8924 (from unit 1 of stratigraphic section on p. 7, from a zone about 16 feet below top of formation).
Crinoid stems and plates
Spirifer centronatus Winchell
cf. *S. rostellatus* Hall
sp. indet.
Composita humilis (Girty)?
Linoproductus sp. undet.
"*Productus*"? sp. undet.
Punctospirifer? sp. undet.
Dielasma? cf. *D. formosum* (Hall)
Pelecypod, 1 sp. undet.

Collection 8923 (from unit 2 of stratigraphic section on p. 7).
Spirifer? sp. indet.

Collection 8922 (from unit 4 of stratigraphic section on p. 7).
Multithecopora? sp. C

Collection 8921 (from unit 7 of stratigraphic section on p. 7).
Caninia sp. C, cf. *C. arcuata* Jeffords
Crinoid stems
Cheilotrypa? sp.
Camarotoechia? sp. indet.
Stenocisma bisinuata (Rowley)
Marginifera? sp. undet.
"*Productus*"? sp. undet.
Rhynchopora cf. *R. illinoisensis* (Worthen)
Pelecypod, 1 sp. undet.

Collection 8920 (from unit 11 of stratigraphic section on p. 7).
Lophophyllid coral
Crinoid stems
Linoproductus sp. undet.

Collection 8919 (from unit 15 of stratigraphic section on p. 7).
Crinoid stems
Punctospirifer? sp. undet.

Collection 8918 (from unit 16 of stratigraphic section on p. 7).
Neospirifer? cf. *N. dunbari* King

Collection 8917 (from unit 20 of stratigraphic section on p. 7).
Zaphrentoid? coral
Caninoid coral, undet.
Tabulate coral (*Chaetetes*) or massive bryozoans
Crinoid stems

Collection 8916 (from unit 23 of stratigraphic section on p. 7).
Zaphrentoid coral, indet.
Crinoid stems

Collection 8915 (from unit 25 of stratigraphic section on p. 7).
Caninia? sp. undet.

COLLECTIONS FROM OR NEAR STRATIGRAPHIC SECTION OF ESCABROSA LIMESTONE IN GUNNISON HILLS, WEST SLOPE OF MAIN PEAK (NE¼SW¼ SEC. 4, T. 16 S., R. 23 E.)

Collection 9400 (from unit 1 of stratigraphic section on p. 8 from a zone 15 feet below top of formation).
Camarotoechia? sp. undet.
Pugnoides? sp. undet.
Spirifer cf. *S. tenuicostatus* Hall
Composita humilis (Girty)?
Rhipidomella? sp. undet.
"*Spiriferina*" cf. *S. salemensis* Weller
Dielasma? cf. *D. formosum* (Hall)

Collection 9199 (from unit 3 of stratigraphic section on p. 8).
Camarotoechia? sp. undet.
Punctospirifer? sp. undet.

Collection ☆9408 (from a zone in an area nearby thought to be stratigraphically less than 20 feet above the base of the Escabrosa).
Archimedes sp. (medium-sized screw)

COLLECTIONS FROM OTHER LOCALITIES

No collections were obtained from the stratigraphic section described in this report from the Johnny Lyon Hills (sec. 16, T. 14 S., R. 21 E.) or from the one described from the Little Dragoon Mountains, 3½ miles northwest of Johnson (sec. 9, T. 15 S., R. 22 E.), but collection ☆9409 came from an area so near that of the last named section that the zone of the collection is thought to be referable to the lower 150 feet of the Escabrosa in the Little Dragoon Mountains section. This collection is, unfortunately, not very important. It consists of a single specimen referred to an undeterminate syringoporoid coral.

Collection ☆9197 is an important one because it contains a single specimen of a crinoid referred by Edwin Kirk to *Agaricocrinus* sp. This is thought to have come from the lower 100 feet of the Escabrosa.

CHARACTER AND AGE OF THE FAUNA

Of the above collections the ones from localities 8905 and 8384 appear to be the most typical of the Escabrosa fauna. The Escabrosa fauna is a well-known one that has been listed, in part illustrated, and discussed in many reports of the Geological Survey [1] and in other publications. It has never been fully described and illustrated, but those who have worked extensively in the West nevertheless know it well. The collections made in connection with the present report are not fully representative and should be considered supplemental to those previously studied by Girty, who is largely responsible for most of the conclusions previously drawn regarding the age of the Escabrosa. Girty's collections were in part reexamined in connection with the present studies and are in part responsible for the age conclusions drawn here.

The brachiopods in the above representative collections and those found in other collections are, with relatively few exceptions, forms found associated in faunas in the West that are considered to be of the age of the Red Wall, Leadville, and Madison limestones, as those formations are widely interpreted. In general, they signify early rather than late Mississippian age.[2] *Spirifer centronatus* Winchell (as widely interpreted in the West) and forms commonly identified as *Camarotoechia metallica* (White), *Punctospirifer subtextus* (White), and *Schuchertella?* cf. *S. chemungensis* (Conrad) when occurring together strongly suggest this early Mississippian age. Other brachiopods in some of the collections from the upper Escabrosa, such as Spirifers of the *S. increbescens* type (*S. pellaensis, S. leidyi, S. keokuk*) suggest very late Osage or younger age. These species are intergradational and the limits of the species overlap; thus, it is very difficult to identify many specimens and to distinguish between variants of these species. In general, this type of *Spirifer* is taken to signify post-Osage strata in the West, but it occurs as well in beds of very late Osage age. The form widely identified as *Spirifer centronatus* Winchell in the West is more commonly found in lower Mississippian rocks that are approximately of Madison age but it may occur in younger rocks as well. Few of the productoid types are diagnostic. The fragmentary preservation of most of the pieces obtained render most of them unidentifiable.

Significant forms identified from the Escabrosa by Girty but not found in the collection made in connection with this investigation include forms listed by him in 1904 as: *Leptaena rhomboidalis* (Wilckens), *Chonetes loganensis* (Hall and Whitfield), and *Syringothyris carteri* (Hall). The names of some of these have since been changed as names have increased or species have been split up in more recent work. Of the corals from beds here called the Escabrosa, Duncan says (memorandum, 1947):

> Corals are not very abundant in these collections. All specimens are fragmentary and some are very poorly preserved. Generic identifications are therefore doubtful, but it was possible to distinguish certain types of rugose corals that seem to be characteristic of the formation. The most common species, which occurs in four or probably five collections, is a small horn coral designated *Triplophyllites?* sp. A. This species is different from but closely related to *Menophyllum excavatum* Girty, which is rather diagnostic of Madison limestone faunas. Other less common zaphrentoid corals are referred doubtfully to *Rotiphyllum* and *Empodesma*. A few caninoid corals were found. These seem to belong to the species group of *Caninia cornucopiae* Michelin which is characteristic of the Lower Carboniferous of Europe. Only one specimen is sufficiently adequate to compare with *Caninia arcuata* Jeffords, described from the lower Mississippian Lake Valley limestone of New Mexico.

A few trilobites collected from one locality (8905) belong to undescribed species that, however, are said by J. Marvin Weller, who examined them, to be "pygidia of lower Mississippian types." Weller has not finished a study of lower Mississippian trilobites and so could not suggest identification. A species from collection 8906 from near the top of the Escabrosa and in beds thought by the writer to be possibly as young as Meramec was identified by Weller as an *Ameura* or closely related form. *Ameura* is a genus commonly thought to be restricted to rocks of Pennsylvanian or younger age, but Weller has found it in upper Mississippian rocks. Of the forms identified as *Ameura* Weller (letter, March 7, 1947) says,

> These specimens are poorly preserved, but they show characters I do not recall in any but one Mississippian species, and I think that they are different from that Chester form. In some ways they suggest comparison with small individuals of Pennsylvanian *Ameura*.

The only crinoid calyx obtained in the collections is the one reported in collection 9197. This calyx was identified by Edwin Kirk who has stated that it is of

[1] For data on the Escabrosa fauna, the following references are especially valuable: Girty's illustrations and lists in U. S. Geol. Survey Prof. Papers 21 and 98K, Darton (1925), and Stoyanow (1936).

[2] In this report, the classification of the Mississippian into two subdivisions, upper and lower, follows a long used custom in the West. Some geologists favor a threefold classification, whereas still others advocate a fourfold subdivision. The boundary between the upper and lower Mississippian as used in this report comes near the top of the Osage group, as nearly as the writer can correlate the western beds with the midcontinent Osage group.

early Burlington age. Blastoids were not found in collections made for the present study, but blastoids thought to be of Burlington age found in the upper part of the Escabrosa near Tucson have been reported by Stoyanow (1926 p. 319–320).

The writers believe that the long-held general correlation of the main body of the typical Escabrosa with the fauna of the main body of the Madison limestone is probably correct. The fauna of the Escabrosa, as collected thus far, does not indicate that success would be obtained were attempts made to zone the Escabrosa. Some attempts have been made to zone rocks of similar age in Arizona and elsewhere but the zones derived do not appear to the writer to be based on adequate data to be truly distinctive or to be reliable for use over very great distances. The same unreliability is true of many of the attempts to zone other formations of Mississippian age in the West and especially of attempts to correlate closely these zones with midcontinent formations. Some of those proposing zones have leaned heavily on evidence from such gradational forms as various species of Spirifers of the *S. increbescens* type, which except for *S. keokuk* and perhaps another or two, are characteristic of post-Osage strata. Because of the difficulty in identifying these midcontinent species in the West, if they are the same species, the zones thus far proposed have only a limited usefulness.

The age of the fauna that is considered to be typical of the Madison limestone is widely considered to be of Osage and Kinderhook age. Some geologists maintain that it is Osage in entirety, whereas others believe that the fauna is nearly all Kinderhook. In the typical Madison limestone there are faunal elements that have been identified with Kinderhook species and other elements that have been identified with Osage species. The writer (Williams) believes that the Madison limestone fauna (and perhaps the Escabrosa fauna) existed during both Kinderhook and Osage time, and that the faunas in the West during these epochs did not change so rapidly as in the midcontinent region, because in the West ecological conditions were uniform longer. Some of the western species identified with species from the midcontinent may not actually be of those species; but even if they are, there is no reason that the species should have precisely the same ranges in the West where ecological conditions were different. The Madson (and Escabrosa) faunas are western faunas that cannot be as yet definitely identified with the faunas from the typical thin formations of the Kinderhook and Osage groups in the Mississippi Valley, where indeed the boundary between the Kinderhook and Osage is still in dispute. The presence of the crinoid genus *Agaricocrinus* in collection 9197 from a zone estimated to be 50 to 70 feet above the base of the Escabrosa is thought by Kirk to indicate a lower Burlington (late Kinderhook or early Osage) age for that part of the Escabrosa in the Dragoon quadrangle.

As is true of the Madison limestone, there is evidence that the Escabrosa in a few places may be younger than of Osage age. Collections 8906 and 8907 at the top of the Tombstone Hills section (p. 6), collection 8924 at the top of the Dragoon Mountain section (p. 7), and collection 9400 at the top of the Gunnison Hill section (p. 8) all contain specimens that suggest species characteristic of post-Osage beds but those specimens that might be of these species are too fragmentary for positive identification. The tentatively identified species that suggest the presence of Meramec or younger beds are *"Spiriferina"* cf. *S. salemensis* Weller, *Spirifer* cf. *S. tenuicostatus* Hall, *S.* cf. *S. pellaensis* Weller, *S.* cf. *S. leidyi* Norwood and Pratten, *Dielasma* cf. *D. formosum* Hall, and *Linoproductus altonensis* (Norwood and Pratten)?. The trilobite pygidium belonging to *Ameura* (coll. 8906) supplements the suggestion of the brachiopods that this collection is younger than Osage. The writer believes that none of these suggestions is strong enough to indicate the presence of beds of Chester age.

Collections containing some of the foregoing species but not any from the stratigraphic sections here described indicate that beds of post-Osage age may also be present in the Mule Mountains. These also are probably pre-Chester.

A suggestion that a fault may cut through the lower part of the section at the Golden Rule Mine, Dragoon Mountains, is made by the tentative identification in collection 8918 of a *Neospirifer*? cf. *N. dunbari* King. This genus is almost restricted in this country to rocks of post-Mississippian Paleozoic age. The one specimen tentatively identified as a *Neospirifer* is incomplete and the ornamentation is poorly preserved. Although it may not be a *Neospirifer*, there is a rather definite suggestion of fasciculation of the *Neospirifer* type. Several collections were made in parts of the section nearby, but nearly all of them are small and composed of forms that cannot be certainly identified. Their age significance cannot therefore be accurately determined. Some of these that have very slight suggestions of Pennsylvanian age are: the presence of lophophyllid type of coral in collection 8920, a possible Pennsylvanian type of tabulate coral in collection 8907, and a *Multithecopora* in collection 8922. These anomalies may be due to: possibly incorrect identification of admittedly poor material, inexact knowledge or assumptions regarding the stratigraphic ranges of these forms in this area, or one or more abedding plane faults.

REGISTER OF U. S. GEOLOGICAL SURVEY COLLECTIONS FROM THE ESCABROSA LIMESTONE THAT ARE OUTSIDE THE STRATIGRAPHIC SECTIONS DESCRIBED IN THIS REPORT

☆8481. Benson quadrangle, Arizona. Altitude 4,800 ft, east side of south tributary of Tombstone Canyon, 100 ft south of road, about 4,000 ft west and 2,000 ft north of southeast corner of Benson quadrangle. James Gilluly, 1937.

☆9197. Dragoon quadrangle, Arizona. About center of sec. 9, T. 15 S., R. 22 E. On hillside above a dry wash that is crossed by 5,000 ft contour line near center of sec. 9. T. W. Amsden and J. S. Williams, July 2, 1944.

☆9408. Dragoon quadrangle, Arizona. Northwest side of small knob in NW¼ SE¼ sec. 9, T. 16 S., R. 23 E. (Gunnison Hills). T. W. Amsden, May 5, 1945.

☆9409. Dragoon quadrangle, Arizona. SW¼ sec. 22, T. 15 S., R. 22 E. Crest of ridge running west from Johnson Peak. T. W. Amsden, May 5, 1945.

PRE-BLACK PRINCE DISCONFORMITY

There seems to be a disconformity between the Escabrosa and Black Prince limestones. The basal member of the Black Prince is shale, with local beds of chert conglomerate. This member contrasts with nearly pure limestone above and below and seems to represent an accumulation of insoluble material from tens or possibly hundereds of feet of the underlying Escabrosa. It is suggested that the relative thinness of the Escabrosa sections measured in the Little Dragoon Mountains and the Johnny Lyon Hills is due primarily to pre-Black Prince erosion because very little if any regional thinning of beds is indicated by the position of the notably cherty limestones which begin 320 to 350 feet above the base in thin and thick sections alike. If thin faunal zones could be established, they might prove or disprove this conclusion. Fossils thus far collected are, however, insufficient and too poorly preserved to permit close zonation, if indeed the fossils differ enough to make thin paleontologic zones recognizable.

BLACK PRINCE LIMESTONE

NAME

The Black Prince limestone is here named from exposures near the Black Prince mine in the Johnson mining district at the east base of the Little Dragoon Mountains. Because of metamorphism at that locality, the type section was measured on the west slope of Gunnison Peak 4½ miles southeast of the mine.

DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The Black Prince limestone crops out on the northeast and southeast flanks of the Little Dragoon Mountains, along the main ridge of the Gunnison Hills, and in the Johnny Lyon Hills. It has not been recognized elsewhere but paleontological evidence suggests that equivalent beds may occur farther south in the upper part of the Escabrosa limestone as mapped.

Though not intrinsically weak the Black Prince limestone is somewhat less resistant than the Escabrosa and tends to form dip slopes. The contact with the overlying Horquilla limestone is marked by a zone of weak rocks which are generally concealed and form conspicuous saddles in several ridges in the northeastern part of the Little Dragoons. The clastic basal member of the Black Prince limestone forms small benches and sags at many places.

STRATIGRAPHY

The Black Prince limestone was first considered an upper member of the Escabrosa limestone which, on the whole, it closely resembles lithologically. It was later mapped as a separate formation because fossils collected from it proved to be upper Mississippian or lower Pennsylvanian and thus intermediate in age between those characteristic of the Escabrosa and Horquilla limestones. The contact with the Escabrosa limestone was drawn at the base of a thin but persistent shale member which contrasts strikingly with the nearly pure limestones above and below. Where the shale is missing, it is extremely difficult to separate the two formations by lithology. The Black Prince, particularly its upper part, is generally pinker than the Escabrosa and contains fewer and smaller chert nodules.

The basal shale member is generally 10 to 20 feet thick. The shale is red to maroon or purple and contains scattered nodules or pebbles of chert and limestone, lenses of chert conglomerate and, locally, thin beds of limestone. It is not well exposed at most places but is present in most if not all parts of the Little Dragoon Mountains, Johnny Lyon Hills and Gunnison Hills where it has provided the basis for mapping the Escabrosa-Black Prince contact. Although fossils collected from a limestone bed in the shale are species found in the Escabrosa, and the lowest upper Mississippian or lower Pennsylvanian fossils were found 10 feet higher stratigraphically, the shale is here assigned to the Black Prince because the paleontologic evidence is too slender for definitely dating the shale member and the stratigraphic evidence, already presented, suggests an unconformity below it.

Above the shale are 100 to 140 feet of nearly pure limestone in 1- to 4-foot beds. The limestone is medium to coarse grained and light gray to pink in color, the pink beds being most conspicuous in the upper part. Fossils are scarce and were found in the lower part only. Chert nodules are present but are small and sparsely distributed.

Above the limestone, and separating it from the highly fossiliferous Horquilla limestone of the Naco group are 30 to 65 feet of weak rocks which are generally concealed and form topographic sags. In the Gunnison

Hills they consist of dull reddish shale interbedded with mottled blue, pink, and white limestone. Because no fossils were found in the zone, it could be assigned to either the Black Prince or the Horquilla. Although its color and other characteristics are more like the shale at the base of the Black Prince than like the olive-green shales found in the lower part of the Horquilla, it was assigned to the Horquilla because the very similarity with the shale at the base of the Black Prince suggests a similar origin—in this case by reworking of the Black Prince, and because the zone is indistinguishable from the overlying rocks where metamorphism has converted the shaly rocks to hornfels and has destroyed the fossils.

REPRESENTATIVE SECTIONS

The following sections, shown graphically in figure 4, are representative of the Black Prince limestone. The first, which is the best exposed, is offered as the type section.

Section of Black Prince limestone in Gunnison Hills, west slope of main peak (NE¼SW¼ sec. 4, T. 16 S., R. 23 E.)

	Thickness (feet)
Horquilla limestone:	
Shale, maroon, with lenses and beds of pink and white limestone. Passes upward into fossiliferous gray limestone.	
Black Prince limestone:	
1. Limestone, light pinkish-gray becoming increasingly pink in upper part; beds 2 to 4 ft thick; scarce chert nodules; lenses of shale in lower 15 ft. (Coll. 9401, 25 to 30 ft above base)	102
2. Shale, deep maroon with light-green mottling; contains scattered nodules of chert and one 6-in. bed of sedimentary breccia with chert fragments as much as 1 in. in diameter. (Coll. 13844, from 2 ft above base.)	17
Thickness of Black Prince limestone	119
Escabrosa limestone:	
Limestone, pinkish gray, with chert nodules; beds 1 to 3 ft thick. Unit 1, page 8. (Coll. 9400 from 15 ft below top.)	

Section of Black Prince limestone in ridge on northeast side of Little Dragoon Mountain (SE¼ sec. 9, T. 15 S., R. 22 E.)

	Thickness (feet)
Horquilla limestone:	
Limestone, highly fossiliferous. (Coll. 9190 from basal 2-ft bed.)	
Covered	32
Black Prince limestone:	
1. Limestone, light-gray becoming pink near top, with very little chert, medium- to coarse-grained; fossiliferous zone near base (coll. 9189 from 10 to 15 ft above base; coll. 9192 from same horizon on other side of small fault); beds 1 to 3 ft thick	116

Section of Black Prince limestone in ridge on northeast side of Little Dragoon Mountain—Continued

	Thickness (feet)
Black Prince limestone—Continued	
2. Covered except for one small outcrop of red shale: much float of fossiliferous limestone (Coll. 9193 from 1-ft ledge outcropping 20 feet below 9192 and probably same bed that is present but concealed in this member)	15
Thickness of Black Prince limestone	131
Escabrosa limestone:	
Dolomite, gray, weathered surface brownish gray with rusty red spots, fine-grained. Unit 1, p. 8.	

Section of Black Prince limestone in northern part of the Johnny Lyon Hills (sec. 16, T. 14 S., R. 21 E.)

	Thickness (feet)
Horquilla limestone:	
Limestone, blue-gray, fine-grained, beds 1 to 3 ft thick, fossiliferous.	
Covered, fragments of shale on surface	39
Black Prince limestone:	
1. Limestone, light-gray with some pinkish mottling, with scarce chert nodules; beds 2 to 4 ft thick	141
2. Shale, red and purple, the latter variety containing rounded chert fragments. Partly covered	27
Total Black Prince limestone	168
Escabrosa limestone:	
Dolomite, light tannish-gray, with nodules of chert. Top 10 ft poorly exposed. Unit 1, p. 9.	

THICKNESS

Measurements of the thickness of the Black Prince limestone are 119 feet in the Gunnison Hills, 131 and 155 feet in the Little Dragoons, and 168 feet in the Johnny Lyon Hills. These measurements indicate a moderate thickening of the formation toward the northwest.

FAUNA AND CORRELATION OF THE BLACK PRINCE LIMESTONE

By James Steele Williams

The Black Prince limestone as now known, occupies a small area in central Arizona. Relatively few collections of fossils are available from it, and those collections are small and not particularly diagnostic. Recognition of the formation is based largely on lithology, as is recognition of all formations in this report.

Fossils are scarce in the Black Prince limestone. Brachiopods constitute most of the few identifiable forms, but one collection consists wholly of composite corals. Only five collections of identifiable fossils were available for study. Of these collections, nos. 9401 and 13844 came from the Gunnison Hills section (p. 14) and collections 9189, 9192, and 9193 came from the section in the Little Dragoon Mountains (p. 14) or from areas nearby that could be readily correlated with units in this section.

COLLECTIONS FROM THE GUNNISON HILLS

Collection 9401 (from lower part of unit 1, upper limestone of stratigraphic section from the Gunnison Hills, see p. 14).
Spirifer cf. *S. pellaenis* Weller
Composita humilis (Girty)?
Linoproductus sp. undet.
Punctospirifer? sp. undet.
Gastropoda, indet.

Collection 13844 (from 2 feet above base of unit 2, lower shale of stratigraphic section from Gunnison Hills, p. 14).
Lithostrotionella sp. undet., several large heads

COLLECTIONS FROM THE LITTLE DRAGOON MOUNTAINS

Collection 9189 (from unit 1, upper limestone of stratigraphic section from Little Dragoon Mountains, p. 14).
Triplophyllites? sp. B
Juresania? sp. undet. (*Pustula*?)
Linoproductus sp. undet.

Collection ☆9192 (from an area so near to the place in the Little Dragoon Mountains from which the stratigraphic section given on p. 14 was taken that it is believed that it can be referred to a horizon equal to that of coll. 9189. For locality data, see register of localities on p. 15).
Camarotoechia? cf. *C. tuta* (Miller)
Linoproductus altonensis (Norwood and Pratten)
Pectinoid pelecypod
Gastropods, indet.

Collection ☆ 9193 (from an area so near to the place in the Little Dragoon Mountains from which the stratigraphic section given on p. 14 was taken that it is believed that it can be referred to the lower 15 feet of the formation as exposed in this section).
Glyptopora, n. sp.
Camarotoechia? cf. *C. tuta* (Miller)
? sp. undet.

CHARACTER AND AGE OF THE FAUNA

As will be clear to most paleontologists, there is not enough evidence in the faunal collections from the Black Prince to allow its age to be closely determined. The collections are few, and the specimens in them few and not amenable to definite identification. To the writer, the collections, when taken together, have a Mississippian facies (a late Osage or younger facies). The heads of *Lithostrotionella* suggest a Mississippian age and more probably middle to late Mississippian age, even though the genus may occur in rocks ranging in age from early Mississippian to Permian. Aside from the species *Linoproductus altonensis* (Norwood and Pratten), no other species can be identified. This species, the *Lithostrotionella*, and the general assemblages suggest that the Black Prince is a lithologic facies that may be of an age equivalent to the part of the Escabrosa that is present locally and that is thought to be of late Osage or early Meramec age. It is also probably equivalent to beds in the lower part of the Paradise formation, although it may be slightly older. At least one collection (9189) suggests that beds of Pennsylvanian age might locally be included in the Black Prince, but the evidence for this hypothesis is not at all strong.

REGISTER OF U. S. GEOLOGICAL SURVEY COLLECTIONS FROM THE BLACK PRINCE FORMATION THAT ARE OUTSIDE THE STRATIGRAPHIC SECTIONS DESCRIBED IN THIS REPORT

☆9192. Dragoon quadrangle, Arizona. Top of ridge, northern part of Little Dragoon Mountains, south central part of sec. 9, T. 15 S., R. 22 E. T. W. Amsden, May 11, 1944.

☆9193. Dragoon quadrangle, Arizona. Northern part of Little Dragoon Mountains, approximately same as locality 9192 (2). 15 ft below zone of coll. 9192. T. W. Amsden, May 11, 1944.

MISSISSIPPIAN-PENNSYLVANIAN DISCONFORMITY

In the area here considered, as much as 200 feet of beds of uncertain age separate beds containing the typical Escabrosa fauna, which is early Mississippian, from beds containing the Horquilla fauna, which is Pennsylvanian. The rocks of doubtful age include upper beds in the Escabrosa limestone of the southern part of the area, which have yielded fossil collections resembling late Mississippian faunules, and also the Black Prince limestone of the northern part of the area, which contains fossils of late Mississippian or early Pennsylvanian(?) age. In the absence of the Black Prince limestone, there is a hiatus between the Escabrosa and Horquilla formations accounting for at least all of Chester time. As has been mentioned by Ransome (1904, p. 42–43) and agreed to by Stoyanow (1936, p. 521), despite the considerable gap between the formations, there is little or no evidence of either erosional or angular discordance between them. In absence of the fossils, a more satisfactory division on physical bases would be at the top of the massive part of the Escabrosa. Accordingly, it is at present impossible to say whether the definitely upper Mississippian deposits still represented in the Chiracahua Mountains to the east (Stoyanow 1936, p. 508–511; Hernon 1935, p. 653–696) formerly extended over this area and were eroded in pre-Naco time or whether the area was emergent during the entire interval. Only a systematic zonation of the Escabrosa and Horquilla could permit a confident answer to this question, but it has not been possible to establish thin zones in these formations.

PENNSYLVANIAN AND PERMIAN ROCKS

NACO GROUP

NAME AND SUBDIVISIONS

In the Bisbee district, Ransome (1904, p. 44–54) defined the Naco limestone as comprising the limestones of Pennsylvanian age overlying the Escabrosa limestone. The thickness was estimated at 3,000 feet. Fossils from the formation were recognized by Girty (1904, p. 46–54) to fall into two groups: one of earlier Pennsylvanian age and another of much later Pennsylvanian age which he compared to the Hueco fauna of west Texas. The Hueco as now restricted—the upper part of the original Hueco—has been classed as Permian(?) by the United States Geological Survey. Stoyanow (1936, p. 522–523) has suggested the restriction of the name Naco to the lower part of the formation as described by Ransome. Although there is evidence of several faunal divisions in the Naco as originally defined, and there is sufficient lithologic distinction between several parts of the formation to permit their being mapped in the area of this survey, it seems probable that a name will long be useful in southeastern Arizona for the entire assemblage of post-Mississippian Paleozoic rocks to which Ransome originally applied the name Naco. We have therefore thought it best to retain Naco as a group term, subdividing the group into formations for this area. There is no more reason to single out the basal part of the Naco as originally described and limit the name to that part than to select any other part. It is highly probable that the divisions here recognized as formations (that is, as fundamental map units) will not prove useful over a very wide area and that use for the name Náco in the original wide sense may long persist.

The Naco group is here divided into six formations. These are, in ascending order, the Horquilla limestone, the Earp formation, the Colina limestone, the Epitaph dolomite, the Scherrer formation, and the Concha limestone. These formations are shown in sections of the Naco group on plate 1.

HORQUILLA LIMESTONE

NAME

The Horquilla limestone is here named from the exposures on the eastern spur of Horquilla Peak, about a mile southeast of Ajax Hill, in the Tombstone Hills. (See fig. 2.)

DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The Horquilla is the most widely exposed formation of the Naco group in this area. Its outcrops cover most of the eastern part of the Tombstone Hills, are widespread in the northwestern foothills of the Mule Mountains, at the south part of the map area, and form much of the main ridge of the Dragoon Mountains north of South Pass (Pearce quadrangle). They are also plentiful in the Courtland and Gleeson districts, where they are much broken by faults, as well as in the thrust area 2 miles northwest of Gadwell Spring at the north foot of the Mule Mountains, all in the Pearce quadrangle. North of Cochise Stronghold the Horquilla limestone is more widely exposed than any other formation of pre-Cretaceous age. It also forms most of the main ridge of the Gunnison Hills and is exposed at a number of places on the flanks of the Little Dragoon Mountains, and on the east slope of the Johnny Lyon Hills.

The Horquilla is less resistant to erosion than the underlying Escabrosa limestone and in several places forms dip slopes of the cuestas held up by the Escabrosa. However, it is not generally a valley-forming formation, but forms gently sloping hills whose relatively smooth contours are interrupted at close and fairly regular intervals by the outcrop of a thicker, more resistant ledge-forming bed.

STRATIGRAPHY

The base of the Horquilla limestone is an obscure surface of disconformity which has not been identified more closely than within a score of feet, stratigraphically. In the Dragoon Mountains and farther south, where the boundary was bracketed most closely by fossil collections, the disconformity appears to fall in a zone of thin-bedded limestones that generally weather to a topographic sag. North of the Dragoon Mountains it appears to fall in a weak zone of shale immediately above the poorly fossiliferous Black Prince limestone.

Above this dubious basal zone, the Horquilla consists of a series of thin-bedded blue-gray limestones with a few thicker beds, as much as 6 or even 8 feet thick. A few beds of reddish-weathering shaly limestone are intercalated in the upper half of the formation as recognized. Most of the limestone is dense and pinkish gray on fresh fracture but a few scattered beds do not show the usual pink tinge, and others, especially the thicker ones, are coarsely crystalline and consist largely of crinoidal fragments, thus resembling much of the Escabrosa limestone.

A feature that is of value in discriminating the Horquilla from both the underlying Escabrosa and the overlying Earp formation is the common presence of small fusulinids, rarely, if ever, exceeding ¼ inch in length and ⅙ in diameter except in the upper part of the formation in the Gunnison Hills. Here the beds closely resemble the Earp in fossil content although they are indistinguishable from the lower part of the Horquilla on a lithologic basis. The larger fauna is chiefly composed of brachiopods and bryozoa.

There is no place in the Tombstone Hills or that part of the Dragoon Mountains in the Pearce or Benson quadrangles where the entire Horquilla limestone is exposed. Faulting has prevented any accurate measurement. It is probable, however, that the following section (a continuation of the section of the Escabrosa measured half a mile southeast of Ajax Hill, on Horquilla Peak) includes nearly the full thickness of the Horquilla, lacking not more than 200 feet and perhaps less than 50 feet of beds referable to this formation. This estimate is based on the fact that geologic mapping in the Pearce-Benson area has nowhere disclosed a section of the Horquilla more than

1,200 feet thick, and one of the thickest (near Tombstone Canyon in the Mule Mountains) appears to be essentially complete. The Horquilla Peak section, which follows and which is shown graphically on plate 1 is therefore offered as the type section of the Horquilla limestone.

Section of Horquilla limestone on spur of east Horquilla Peak, Tombstone Hills

	Thickness (feet)
Horquilla limestone:	
Eroded. It is believed that not more than 200 (perhaps less than 50) ft of beds are missing from the top of this section.	
1. Limestone, thin-bedded (2 ft or less), some with purplish to pinkish cast, mostly gray on fresh fracture; a little nodular chert	41
2. Limestone, massive ledge (Coll. 8479)	6
3. Limestone, thin-bedded, like unit 1 except for absence of purple or reddish cast on fresh fracture	48
4. Limestone, massive ledge	7
5. Limestone, like unit 3	22
6. Limestone, a massive ledge with one thin reddish shaly parting near the middle. Aphanitic, gray on fresh fracture, some chert, very fossiliferous	33
7. Limestone, thin-bedded, gray, fossiliferous	43
8. Limestone, thin-bedded below, but passing upward to thick, massive ledge at top. (Coll. 8934 at top)	35
9. Limestone, massive, very cherty, with irregular masses of red chert, many spherical, others concretionary and subparallel to bedding, forms ledge	6
10. Limestone, thin-bedded, platy, weathers reddish and reddish brown, current-bedded, very fossiliferous, forms slope	12
11. Limestone, like unit 9	6
12. Limestone, like unit 10	10
13. Limestone, like unit 9	13
14. Limestone, like unit 10	170
15. Limestone, light-gray, massive with large chert nodules. Makes strong ledge that can be traced for a long distance	9
16. Limestone, shaly, thin platy, weathers buff and red, pink on fresh fracture; forms saddle, many bryozoa. (Coll. 8933 from middle of unit)	77
17. Limestone, chiefly in beds 2 to 6 in. thick, dense fossiliferous, pinkish gray on fresh fracture, cherty, with some concretionary chert masses parallel to bedding. A few chert nodules show fusulinid casts. A few thicker, crinoidal beds as much as 6 ft thick occur, but they do not contrast notably in the topography with the thinner beds. (Coll. 8932, from 180 ft above base)	287
18. Limestone, light-gray, pinkish-gray on fresh fracture, in beds 2 ft or less thick; much pink-weathering chert, with some irregular masses of nodular black chert as much as 6 or 8 in. across. (Colls. 8387 and 8931 at top, coll. 8386 in middle of unit)	122

Section of Horquilla limestone on spur of east Horquilla Peak, Tombstone Hills—Continued

	Thickness (feet)
Horquilla limestone—Continued	
19. Limestone, fossiliferous (fusulinids), weathers slightly pink, in beds that are 1 ft or less thick; more bluish gray toward the top. The lower part forms a saddle, mapped as base of Naco group. (Colls. 8930 and 8385 at top)	52
Horquilla limestone, exposed	999
Escabrosa limestone:	
Limestone, thin-bedded, chiefly gray on fresh fracture but with some pink. Unit 1 of Escabrosa limestone section on page 6.	

The contact of the Horquilla limestone with the overlying Earp formation is not ordinarily well defined. Thin shales occur in the Horquilla at intervals for a long distance below the top. They become dominant over the limestone interbeds at the base of the Earp formation, which is arbitrarily chosen at this point. However, the shales offer a zone of weakness for bedding plane slippage and are commonly much sheared. In many localities where the Horquilla and Earp are in normal succession the contact is a fault, commonly of unknown stratigraphic displacement. The characteristic beds of the Earp formation are largely in its upper part; thus accurate evaluation of the stratigraphic effect of these bedding faults is ordinarily impossible. In the area chosen for the type locality of the Earp formation there is no appreciable faulting at this horizon but here, unfortunately, only a few score feet of the Horquilla limestone are represented in the underlying exposures. In the exposures at the west foot of Colina Ridge, in sec. 35, T. 20 S., R. 22 E. in the southern part of the Tombstone Hills, it is probable that such faulting as occurs is within the Earp formation rather than at its base, although exposures are not quite clear. If this is true, the section on Horquilla Peak probably gives a complete representation of the Horquilla formation

Sections measured farther north are much thicker. Thus in the Gunnison Hills an apparently unfaulted section of the Horquilla limestone has a thickness of 1,600 feet, separated from rocks of the Earp formation by a covered interval equivalent to an additional 175 feet of beds. This is the only measurable section of the entire Horquilla limestone in the northern part of the area. Partial sections in which the top is concealed beneath overlapping alluvium measure 1,050 feet in the Little Dragoon Mountains and 1,325 feet in the Johnny Lyon Hills. The Gunnison Hills section is given below and shown graphically on plate 1.

Section of Horquilla limestone on main ridge of Gunnison Hills, ¼ mile north of main peak (northern part of sec. 4, T. 16 S., R. 23 E.)

	Thickness (feet)
Earp formation:	
Limestone, blue-gray, with many fusulinids. (Coll. 9402G.)	
Covered interval	176
Horquilla limestone:	
1. Limestone, light-gray to blue-gray, similar to limestones below except essentially free from chert. (Coll 9402F)	37
2. Covered	47
3. Limestone, like unit 9 but perhaps lighter gray and pinker on fresh fracture. (Coll. 9402E, from 270 ft above base; coll. 9402D, from 155 ft above base)	360
4. Limestone, sandy, fresh fracture dark gray, weathered surface brown. (Coll. 9402C)	2
5. Limestone, like unit 9	293
6. Limestone, like unit 9 except that light-gray fine-grained and partly dolomitic beds are fairly conspicuous (similar beds present but scarce below)	75
7. Limestone, like unit 9. (Coll. 9402B, from top 30 ft; coll. 9402A, from 115 to 135 ft above base)	215
8. Shale, light-tan to reddish-brown, calcareous; a few beds as much as 1 ft thick	30
9. Limestone, blue-gray, commonly with pinkish, tan, or dark-gray mottling, mostly fine-grained but some beds coarse-grained, fossiliferous; contains white to blue-black chert nodules weathering brown (some larger than 1 by 3 ft but mostly smaller); limestone beds 1 to 3 ft thick except for occasional beds as thick as 5 feet; a few 1- to 3-ft beds of olive-green shale. The unit forms a ribbed surface because of the presence of ledge-forming limestone beds at fairly regular intervals. (Coll. 9402, about 300 ft above base.)	425
10. Siltstone, olive-green, in beds less than 6 in. thick; weathers into angular blocks; one 2-ft limestone bed near the base	17
11. Limestone, like unit 9; fusulinids in lowest bed	54
12. Shale, maroon to purple, with greenish mottling	40
Thickness of Horquilla limestone	1, 595
Black Prince limestone:	
Limestone, pinkish-gray.	

EARP FORMATION

NAME AND TYPE LOCALITY

The Earp formation is here named from Earp Hill in sec. 5, T. 21 S., R. 23 E. on whose south slope the lower part is well exposed (fig. 2). There is no continuous, unfaulted section of the entire formation in the area of the northern Mule Mountains, Tombstone Hills, or the Dragoon Mountains, included in the Pearce and Benson quadrangles. However, the presence of a very distinctive lithologic member in the formation permits piecing the section together. Accordingly, the type section is here designated as extending from the saddle south of Earp Hill up to a conspicuous mottled, pink and gray limestone indicated in the section following, and then (to avoid the faulting at this locality) is completed by the excellently exposed section above this mottled bed about half a mile to the east on the same slope. Confidence in the identity of the mottled bed in these localities is strengthened by its persistence and characteristic appearance over wide areas in the Tombstone Hills. It is present at the foot of Colina Ridge, northeast of the Prompter mine, and all along the foot of the ridge northeast of Epitaph Gulch, as well as on the south side of Government Butte, to the south. All these localities are shown on the Benson quadrangle map. There is only a short gap between the two sections that are here synthesized as the Earp formation.

DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The Earp formation crops out widely in the Tombstone Hills, in the low hills between these and the Mule Mountains, in the northwestern Mule Mountains, and in the hills near Gleeson. It has not been recognized in the Courtland district, though the overlying Colina limestone is present, but the intimate slicing of this district by thrust faults and the evident susceptibility of the Earp formation to serve as a gliding plane probably account for this. It is also found on the west slope of the Dragoon Mountains south of Black Diamond Peak (Pearce quadrangle), in the main Dragoon ridge north of Mt. Glen (Pearce quadrangle), in the Gunnison Hills, in the faulted area on the southeast flank of the Little Dragoon Mountains, and in one small area on the east slope of the Johnny Lyon Hills (Dragoon quadrangle).

Most of the areas underlain by the Earp formation are low. There are several fairly resistant ledges of limestone and dolomite in the formation, especially in its upper part, but the shales of the lower part of the formation are weak and their erosion undermines the higher ledges. The characteristic outcrop of the formation is thus a gentle though interrupted slope at the base, steepening upward to a fairly persistent ledge beneath the relatively more resistant Colina limestone overlying it.

STRATIGRAPHY

The base of the Earp formation is only locally exposed, owing to its intrinsic weakness toward the forces of erosion, to its position between more massive and competent beds which has led to its shearing during the deformation of the rocks, and to its apparently fortuitous position at several localities along normal faults, where it is either much dragged or largely concealed by talus.

The one really good exposure of this part of the formation in the Tombstone-Dragoon Mountain area is that on the lower slopes of Earp Hill, due south of its crest. Here, there appears to be no erosional or other discordance with the underlying Horquilla limestone. As given in detail in the following section, the base of the Earp is arbitrarily taken where the thin shaly limestones and reddish shales become dominant over the more massive limestones characteristic of the Horquilla. Much shale, a little sandstone, and a few beds of limestone and shale conglomerate occur somewhat higher in the section. These, in turn, give way upward to more massive limestone with a few very conspicuous beds of dolomite that weather to a brilliant orange or red. These beds, though only 1 foot to 5 or 6 feet thick and interbedded with limestone that differs little from the overlying Colina, form a characteristic assemblage and constitute the best clue to the presence of the formation. They are commonly crossbedded and somewhat cherty. A few thin sandstones are found associated with these "orange dolomites." The topmost of these dolomite beds is taken as the top of the Earp formation, though a local stray sandstone is found at higher levels in some places.

Thus both boundaries of the Earp formation are arbitrary, though, as a whole, the formation contains a much higher proportion of clastic deposits than either of the adjacent formations.

The following section is presented as the type section of the Earp formation.

REPRESENTATIVE SECTIONS

Section of Earp formation, on south side of Earp Hill (top part measured about half a mile east-southeast of the crest)

	Thickness (feet)
Colina limestone:	
Limestone, almost black on fresh fracture, weathers dark gray. In beds 2 to 4 ft thick.	
Earp formation:	
1. Dolomite, thinly laminated, varvelike, sandy, pink on fresh fracture, weathers to conspicuous orange-tan, dense, with sporadic nodules of coarse calcite as much as 2 in. across, but averaging ½ in	5½
2. Limestone, blue-gray on weathered surface, very dark-gray on fresh fracture. Forms ledge	11
3. Limestone, red shaly, poorly exposed, forms slope	10½
4. Limestone, dark-gray, forms a low ledge	2⅓
5. Limestone (or limy shale), red shaly, poorly exposed, forms slope	5½
6. Limestone, dark-gray, dense, in beds about 2 ft thick, forms very prominent ledge	23
7. Sandstone, soft, shaly, weathers to red-brown, slope-former, with a few thin limestone ledges	17
8. Sandstone, brown, well-cemented, caps ledge	⅓
9. Dolomite, like unit 1 except that no calcite nodules occur	1⅔
10. Limestone, blue-gray, dense, with beds from 2 to 10 in. thick	4½
11. Concealed, probably limestone	2

Section of Earp formation, on south side of Earp Hill—Con.

	Thickness (feet)
Earp formation—Continued	
12. Dolomite, pink on fresh fracture, weathers orange tan, varvelike laminations, with some crossbedding, slightly sandy, with thin intraformational breccia at top	3
13. Concealed	1
14. Dolomite, like unit 1	2½
15. Concealed, probably shale or thin-bedded limestone	4½
16. Dolomite, like unit 1	3
17. Alternations of thin-bedded (less than 6 in.) limestone and dolomite at the base, passing upward into maroon shale which constitutes most of the member	18
18. Limestone, dense, pink to dove-colored on fresh fracture, weathering to a very pale blue gray; average bedding about 3 ft; 2 or 3 partings of orange-weathering dolomite 1 or 2 in. thick, considerable chert in small nodules. Top 2 ft contain pink shaly material anastomosing through the rock. (Coll. 8967)	24
19. Dolomite, weathering orange, and limestone, pink, forming a secondary ledge	8
20. Limestone, a single massive bed, mottled with pink and white. A little chert but free from dolomite. This "marker" bed has been recognized over a wide area	22½
(Section shifted to a point directly south of summit of Earp Hill—about 2,000 ft west of the line where the above section was measured—for the lower part of the Earp formation, which follows.)	
21. Limestone, same bed as unit 20. A strike fault cuts the section a few feet above top of this unit.	
22. Limestone and shale, poorly exposed, form a slope with a 2-ft ledge of shaly limestone that weathers very dark brown near bottom of unit. (Coll. 8970)	23
23. Limestone, pink, mottled with orange-weathering dolomite; very cherty, with large irregular blotches of brown-weathering chert especially prominent in the dolomitic parts; forms a massive ledge	11
24. Limestone, blue-gray, shaly, not well-exposed	8
25. Limestone, blue-gray, varying irregularly along and across the strike to pink and dove-colored dolomite. Much nodular chert that weathers to a conspicuous orange, especially prominent toward the top where it commonly forms a nearly solid ledge 6 in. thick; a massive ledge	4½
26. Concealed; probably soft limestone	9½
27. Limestone, weathering light gray, somewhat mottled by dolomite that weathers to a yellowish brown; contains much chert, weathering orange to red, in nodules and lenses as much as 2 ft long by 2 in. thick	3½
28. Limestone, dense, weathering light gray, with silicified crinoid stems. Average bed about 3 ft	9½
29. Concealed; probably mostly red shale and shaly limestone	37

Section of Earp formation, on south side of Earp Hill—Con.

Earp formation—Continued	*Thickness (feet)*
30. Limestone, coarsely crystalline, pinkish-gray on fresh fracture, weathering to a peculiar dark yellowish-brownish-gray; highly fossiliferous, with many gastropods. (Colls. 8969 and 8968)	2
31. Alternating shale, red, and limestone, blue-gray, mostly nodular, shaly, and in beds as thick as 1 ft. Not well exposed, forms slope	47
32. Sandstone, concretionary, maroon on fresh fracture, weathering to dark brown; in part crossbedded, in part evenbedded, grades downward into unit 33; forms ledge	12
33. Interbedded thin shaly sandstone, sandy shale, and blue-gray shaly limestone. Much of the limestone is nodular and concretionary, though some of the nodules appear to be abraded and may have undergone some transportation. The member as a whole is soft, red-brown to maroon, and forms a slope	42
34. Limestone, dense, dove-colored, somewhat shaly and nodular in lower part but massive and less shaly above; carries many brachiopods; forms a ledge. (Coll. 8508)	5
35. Sandstone, soft-gray to reddish-brown, crossbedded, very limy and shaly, thin-bedded, forms slope	75
36. Limestone conglomerate, carries angular to subrounded fragments as much as 2 in. across and averaging about ¼ in., of brown shale and gray limestone in a matrix of gray limestone; soft at base, more resistant upward	18
37. Limestone, dark-gray on weathered surface, highly foraminiferal, forms ledge. (Coll. 8507)	2
38. Limestone, red, locally weathering orange, shaly, forms a saddle	7
39. Limestone, dove-colored, weathering medium gray, stylolitic, carries many Foraminifera	7
40. Shale, red, with a poorly exposed orange-weathering ledge of dolomite near the base and with more limestone interbeds upward	51
41. Limestone, dark-gray, weathers medium gray, crystalline, forms a low ledge	2
42. Concealed; probably shaly limestone or limy shale	18
43. Limestone, dove-colored, weathers medium gray, dense, massive	4
44. Concealed; probably shaly limestone	3
45. Sandstone, limy, locally silicified, fine-grained (average ¼ mm), weathers to a conspicuous red-brown	3½
46. Concealed; probably thin limestone or shale	3½
47. Limestone, gray, pink along joints, massive, aphanitic	4½
48. Concealed; probably thin-bedded limestone	3½
49. Limestone, dark pinkish-gray, weathers to a medium gray	1½
50. Limestone, soft, thin-bedded, pinkish, with a 2-ft bed of orange-weathering dolomite near the middle	7
Total Earp formation	595

Horquilla limestone:

Limestone, aphanitic, gray, pink along joints, generally thick-bedded (top bed is 4 ft thick).

The intensely disturbed structure and the tendency for the shaly members of the Earp formation to shear out makes this the only section in the northern Mule Mountains, Tombstone Hills, or southern Dragoon Mountains that seems to offer any possibility of being complete. The only other section measured by Gilluly was in the spur southwest of the Golden Rule mine. This section is given below and is shown graphically on plate 1.

Section of Earp formation on spur southwest of the Golden Rule mine, Dragoon Mountains

Colina limestone:

Limestone, dark-gray, somewhat sheared near the base and there mottled with pink, otherwise dull gray throughout.

Comformable contact.

Earp formation:	*Thickness (feet)*
1. Limestone, blue-gray, mottled with pink	2
2. Shale	3
3. Sandstone, brown, dolomitic	7
4. Shale	10
5. Limestone, mottled, somber brown and gray, in beds 1–4 ft thick, averaging about 2 ft	36
6. Sandstone, yellow-buff, weathering reddish brown fine-grained, limy	8
7. Limestone, mottled, pink and blue, weathering reddish gray, in beds that average 1 to 2 ft thick and are as thick as 6 ft, interbedded with subordinate blue-gray and pinkish shale	51
8. Dolomite, pinkish-gray on fresh fracture, weathering to a conspicuous orange tan, massive, dense	2
9. Shale, purplish	6
10. Interbedded limestone, shale, sandstone, and dolomite. The limestone is blue gray, in beds ½ to 2 ft thick, dolomite is pinkish gray, weathering orange tan, in beds of about the same thickness, a few thin brown-weathering sandstones and considerable purplish shale make up more than half the unit	55
11. Shale, purple	12
12. Limestone, dark blue-gray and dense on fresh fracture, weathering to very dark gray, in beds 2 to 4 ft thick	10
13. Sandstone, very light-gray to almost white on fresh fracture, weathering to light brown, crossbedded, ripple-marked, in beds as thick as 4 ft	19
14. Limestone, fine-grained, pink on fresh fracture, weathering to purplish gray and brown gray, in beds 1 to 3 ft thick; interbedded with thin shale partings	25
15. Sandstone, dolomitic, gray on fresh fracture, weathering to dark brown, current-bedded, ripple-marked	8
16. Interbedded shale and sandy dolomite. The shale is purplish, and makes up about three-fourths of the unit; the dolomite layers are 1 to 2 ft thick and weather to an orange tan	53
17. Breccia, sandstone and dolomite fragments, with some irregular chert nodules	1
18. Sandstone, dolomitic, varying to sandy limestone; current-bedded	4

Section of Earp formation on spur southwest of the Golden Rule mine, Drogroon Mountains—Continued

Earp formation—Continued	*Thickness (feet)*
19. Limestone and shale in alternating beds, with a few discontinuous thin beds of dolomite that weather orange tan. The limestone is mottled pink and white, and contains irregular chert masses that weather brown. Limestone beds range from 1 to 3 ft in thickness, the interbedded shales are purple and green	60
20. Limestone, conspicuously mottled pink and white, forms a prominent ledge	7
21. Shale, bluish	23
22. Limestone, ledge-forming, dolomitic and weathering orange in the top few inches, gray below	3
23. Shale, greenish-gray	1
24. Limestone, partly coarsely crystalline marble, mottled pink and white, forms prominent ledge	15
25. Alternating green shale, gray limestone, and pink and white mottled limestone. The limestone ledges are 2 to 4 ft thick, the shale somewhat thicker	107
26. Limestone, pinkish-gray, weathering to a mottled brown, forms strong ledge	5
27. Shale, greenish-gray	7
28. Limestone, bluish-gray, weathering to a red brown	8
29. Shale, green, micaceous, grading down into unit 30	4
30. Sandstone, platy, shaly, current-bedded, gray on fresh fracture, weathering brown	5
31. Limestone, pinkish-gray, weathering to a mottled brown, forms ledge	7
32. Shale, platy, limy	8
33. Limestone, mottled with dolomite, pink on fresh fracture, weathering yellow	2
34. Limestone, thin-bedded, reddish, shaly	8
Thickness of Earp formation	577

Conformable contact.

Horquilla limestone:

Limestone, in 2-ft beds, fine-grained, pale blue-gray on fresh fracture, weathering almost white except for one bed near top that weathers very dark gray. Unit 1 of Horquilla limestone of section measured here.

Farther north, in the part of the area studied by Cooper, the only complete section of the Earp formation is in the Gunnison Hills about 5½ miles northwest of the Golden Rule locality. This section, which is given below, contrasts with those previously given in being much thicker and having a conspicuous conglomerate bed (unit 35) between the lower part with light-colored limestones and many fusulinids, and the upper part with abundant dark-gray or black limestones and a poorly preserved gastropod-cephalopod fauna resembling that in the Colina limestone. In the Dragoon quadrangle no fusulinids have been found above the conglomerate. Because the relationships suggest a time-break of possible significance, Cooper has subdivided the Earp just below the conglomerate in mapping the Gunnison Hills area.

Section of Earp formation on east side of Gunnison Hills, 1 mile north of main peak (sec. 33, T. 15 S., R. 23 E.)

	Thickness (feet)
Colina limestone:	
Limestone, dark-gray to blue-black, fine-grained, cut by calcite veinlets, free from chert; occasional short covered intervals which may be marl.	
Earp formation:	
1. Sandstone, fine-grained, calcareous, weathering brown	7
2. Limestone, dove-gray	4
3. Marl, partly covered	4
4. Sandstone, fine-grained, calcareous, weathering brown	1½
5. Covered, probably marl	11
6. Limestone, blue-black, fine-grained; contains gastropods; beds mostly less than 1 ft thick	19
7. Marl, light-gray	11
8. Limestone, very dark-gray to dull black, with thin calcite veinlets; beds as thick as 3 ft	20
9. Covered, except for one mottled light- and dark-gray limestone outcrop	14
10. Sandstone, calcareous, fresh fracture light gray, weathered surface brown	13
11. Covered; probably shale or marl	11
12. Limestone, dark-gray to blue-black, with irregular seams of red silt	13
13. Covered	5
14. Limestone, gray with blue mottling	½
15. Dolomite, light reddish-tan, fine-grained with silty laminae	2½
16. Covered, probably marl with 6-in. sandstone bed	6
17. Sandstone, calcareous, fresh fracture gray, weathered surface brown, with conspicuous crossbedding and ripple marks	11
18. Covered; probably marl	7
19. Limestone, gray with greenish mottling; beds 4 to 6 in. thick	9
20. Limestone, dark-gray; beds 1 to 4 ft thick	13
21. Dolomite, tan, fine-grained, silty	1
22. Sandstone, calcareous, weathering brown; beds less than 4 in. thick	4
23. Marl, light-gray to pinkish-gray	9
24. Dolomite, light-tan, fine-grained, with laminae of silt	6
25. Limestone, very dark-gray; contains gastropod fragments; beds as thick as 1 ft	15
26. Sandstone, calcareous, weathered surface brown, fresh fracture gray, thin-bedded (less than 6 in.)	13
27. Marl, light-colored	6
28. Limestone, gray, with many echinoid spines. (Coll. 9404D)	4
29. Limestone, dark-gray, with many cephalopods. (Coll. 9404C, from top 2 ft)	7
30. Limestone, gray with tan mottling, fine-grained	2
31. Dolomite, aphanitic, weathered surface tan, fresh fracture greenish gray	1
32. Mostly covered; a few outcrops of thin-bedded, rusty-weathering, calcareous sandstone in top 40 ft	56

Section of Earp formation on east side of Gunnison Hills, 1 mile north of main peak—Continued

Earp formation—Continued	*Thickness (feet)*
33. Sandstone, calcareous, fine-grained, thin-bedded (less than 3 in.), fresh fracture pinkish gray, weathered surface brown	4
34. Covered	23
35. Conglomerate, grading upward into sandstone with scattered pebbles; pebbles of sandstone, chert, and limestone with diverse colors and textures; pebbles as much as 10 in. across but mostly smaller	11
Thickness of upper member (units 1–35)	344½
36. Covered, probably marl or clay	16
37. Limestone, pink, silty, thin-bedded (less than 1 ft); partly covered	14
38. Limestone, pinkish-gray, with chert nodules and 1 ft of tan-colored chert at top; fossiliferous, commonly preserved in chert. (Coll. 9404B)	7
39. Limestone, white to light-gray, fine-grained, beds 4 to 6 in. thick; limestone conglomerate 1 ft thick at base	8
40. Covered	5
41. Limestone, pinkish-gray, with small brown silica nodules (⅛ by ¼ in.)	1
42. Covered	30
43. Limestone, pink to blue-gray irregularly mottled by tan; beds less than 6 in. thick	8
44. Covered	8
45. Limestone, dolomitic, very fine-grained, blue-gray with yellowish mottling	2
46. Covered	8
47. Limestone, pink with purple mottling	2½
48. Covered; probably pink shaly limestone	10
49. Limestone, white with pink mottling. (Coll. 9404A)	8
50. Covered; probably pink marl	28
51. Limestone, light pinkish-gray with a little yellow mottling; beds as thick as 3 ft	25
52. Limestone, dove-gray, fine-grained, with small chert nodules; beds 1 to 2 ft thick	15
53. Covered	10
54. Limestone, blue-gray; with many fossils, especially large Spirifers. (Coll. 9404)	13
55. Covered	11
56. Limestone, mottled pink and yellow, fine-grained	13
57. Limestone, dark blue-gray becoming pinkish-gray near top; seams of red silt; beds 6 to 12 in. thick	19
58. Covered	10
59. Dolomite, weathering orange or tan, fine-grained, with varvelike laminations	2
60. Limestone, dove-gray to pinkish-gray with a little orange mottling; contains a little orange-weathering chert; fossiliferous. (Coll. 9403D, from this member 500 to 1,000 ft west of place measurement made)	10
(Remaining units were measured about 1,000 ft west of locality where above units were measured. Unit 61 forms a conspicuous ledge between the two parts of the section.)	
61. Limestone, gray, in beds 2 in. to 2 ft thick except for massive 4-ft bed at the base; the top 2 ft is fine-grained dolomitic limestone weathering light reddish tan and having varvelike laminations and orange-colored chert nodules	36
62. Covered except for several small outcrops of light-colored marl and a 1-ft ledge of tan limestone	40
63. Limestone, gray, with many fossil fragments (Coll. 9403C)	2
64. Shale, interbedded with reddish-brown (weathered surface) calcareous sandstone; sandstone contains nodules of gray limestone; one 2-ft limestone bed included	30
65. Limestone, pinkish-gray, in beds 1 to 2 ft thick, with two 2-ft layers of pale-green mudstone(?)	28
66. Sandstone, calcareous, fine-grained	14
67. Limestone, alternating with covered intervals which may be shale or marl; the limestone (more than half the unit) is mostly pinkish gray but in part tan and fine grained	51
68. Sandstone, calcareous, fine-grained, weathering brown, with several feet of shale at base	25
69. Limestone, gray, in ledges separated by covered intervals which are probably shale. (Coll. 9403B)	22
70. Shale, calcareous, mostly covered, with a few ledges of gray limestone as thick as 2 ft	46
71. Limestone, blue-gray, with many fusulinids; some intraformational conglomerate; beds 6 to 12 in. thick	12
72. Sandstone, calcareous, ripple-marked, weathering rusty brown; some covered intervals which are probably shale or marl	26
73. Limestone, gray, mottled	3
74. Shale, greenish, with several feet of sandstone at base; partly covered	15
75. Limestone, gray, with many fusulinids. (Coll. 9403A)	13
76. Limestone, reddish-tan, fine-grained, with small (less than ½ in.) silica nodules	1
77. Sandstone, calcareous, weathering rusty brown, interbedded with minor amount of shale or marl	31
78. Limestone, mottled blue-gray and pinkish, with silty layers in upper part; a few light-tan limestone beds, partly covered	84
79. Sandstone, calcareous, fine-grained; weathered surface brown, fresh fracture gray; beds 1 to 12 in. thick	19
Thickness of lower member (units 36–79)	781½
Thickness of Earp formation (units 1–79)	1,126

Horquilla limestone:

Limestone, blue-gray to gray with some pinkish mottling; a few fine-grained limestone beds weathering light tan; beds 1 to 3 ft thick.

THICKNESS

Owing to the shearing out of the Earp formation in many places, no other sections of the formation within the mapped area can be accurately measured. However, the broken sequences exposed west of Dragoon Camp (Pearce quadrangle) suggest that a thickness of 600 feet is probable in that locality. This is in close agreement with the measurements on Earp Hill, 595 feet, and near the Golden Rule mine, 577 feet, but further emphasizes the contrast with the single measurement in the Gunnison Hills, 1,126 feet. Although the Gunnison Hills section is well exposed and apparently free from faults, confirming measurements in neighboring areas are required before it can be concluded that the formation thickens abruptly toward the north. Only partial verification is now available—a measurement of 363 feet for the upper member about a mile northwest of the Gunnison Hills section. The corresponding thickness in the complete section is 344½ feet, the difference being within the limit of accuracy of measurement. As both boundaries of the Earp formation are arbitrary planes in a transitional series, the subjective factor of selection must be considered. The thickness measured in the Gunnison Hills cannot be reduced more than 237 feet by any reasonable selection of boundaries. The authors of this report are in substantial agreement on the boundaries here selected.

CONDITIONS OF DEPOSITION

As far as known, the Earp formation is wholly of marine origin. It clearly records a shallower sea than that prevailing at the time of deposition of the Horquilla limestone or of the overlying Colina limestone. No basal conglomerate or other evidence of emergence between the deposition of the Horquilla and the Earp has been recognized. The conglomerates present in the lower third of the formation are apparently wholly intraformational—their pebbles appear to be merely broken fragments of the immediately underlying beds—perhaps produced by big storms.

The conglomerate at the base of the upper member in the Gunnison Hills (unit 35, p. 22), but absent in the southern sections, differs from the lower conglomerate beds in being a heterogeneous mixture of sandstone, limestone, and chert fragments, of diverse colors and textures. Many of the fragments are evidently derived from beds immediately below, but some can be matched only scores of feet lower in the section, and others, particularly small round jasper fragments, cannot be certainly matched with any of the underlying rocks. Mixing of fragments from a considerable area is clearly indicated. The importance of this conglomerate within the Earp will not be known until more paleontological information is available and surrounding areas have been mapped.

The intercalated clastic beds of the upper part of the Horquilla resemble those of the lower part of the Earp very closely. It seems likely, therefore, that the conditions during deposition of the Earp differed from those of Horquilla time only in the predominance of such periods of clastic deposition over those of limestone deposition. No evidence of a sudden or pronounced change in relations of land and sea has been recognized in the sedimentary rocks, nor do the fossils thus far collected suggest any considerable break in time.

COLINA LIMESTONE

NAME

The Colina limestone is here named from its excellent exposures on the west side of Colina Ridge, a mile south of Horquilla Peak (fig. 2).

DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The Colina limestone is widespread in the Tombstone Hills and at the west foot of the Mule Mountains. Only small slices of the formation are found in the southeastern Dragoon Mountains. There are no outcrops of this formation in the south end of the main ridge of the Dragoons, but it is present near the crest west of Dragoon Camp. It is also found in smaller bodies north of Mt. Glen, near Middlemarch (all on the Pearce quadrangle map), southeast of the Fourr ranch (Benson quadrangle), and at the north tip of the range. North of the Dragoon Mountains the only known outcrops of the formation are in the eastern and northern parts of the Gunnison Hills.

Where the Colina limestone is thick-bedded it is a resistant formation and forms cliffs only slightly less precipitous than those of the Escabrosa. The thinner beds, although practically free from shale, tend to produce shelves in the topography, and there are enough of them to reduce the boldness of outcrops of the formation to one intermediate between that characteristic of the Escabrosa and that of the Horquilla.

STRATIGRAPHY

As mentioned in the description of the Earp formation, the lower boundary of the Colina limestone was taken arbitrarily at the highest of the dolomite beds that weather to an orange-red surface. In the type area this places nearly all of the clastic rocks—the sandstone and shale beds—in the Earp formation, although there is a local stray sandstone bed considerably higher in the section (in the lower part of the Colina limestone). Outside the type area the base of the Colina limestone is taken where the interbedded sandstones, shales, marls, and limestones characteristic of the Earp formation pass over to the relatively uniform dark limestones of the Colina—even though the highest "orange dolomite" is as much as 150 feet lower stratigraphically.

The most characteristic lithologic feature of the Colina limestone is the dominance of dense limestone that appears very dark gray to almost black on fresh fracture. The field name adopted for the formation was "the black limestone" which emphasizes its most conspicuous distinction. Similar beds are locally found in other formations of late Paleozoic age but elsewhere are rarely more than a few feet thick. It seems safe to conclude that in central Cochise County any continuous section of dense limestone that is dark gray to black on freshly fractured surfaces and is as much as 25 feet thick is part of the Colina limestone. This has been verified by fossils collected in many localities and no inconsistencies have been discovered. It should be pointed out that, although the Colina limestone generally weathers to dark gray, it locally weathers to light gray or almost white, despite the very dark color on fresh fracture.

A further feature of value in discriminating the Colina limestone from the other limestone formations is the abundance of gastropods in it. Several of these gastropods are very striking, notably a very large obtuse-angled *Omphalotrochus*. It attains a height of 5 or 6 inches and specimens 3 or 4 inches high are common. Brachiopods are present but far less commonly than the gastropods—a relation that is reversed in the Horquilla limestone. Chert is not abundant in the Colina limestone and where present commonly forms irregular nodules rather than lenses or beds as it does in the Horquilla.

The upper limit of the Colina limestone, like the lower, appears to be quite arbitrary, for no disconformity has been recognized. The transition to the overlying Epitaph dolomite takes place through a zone of variable thickness in which the limestone is mottled with dolomite in proportions that increase upward until it finally passes into massive dolomite. In places this transition takes place in a zone as much as 30 feet thick, but more commonly it is less than 4 feet between the essentially non-dolomitic limestone of the Colina and the essentially non-calcitic dolomite of the basal Epitaph. As the dolomite of this zone is apparently secondary, the transition beds are here included in the Colina limestone, though the zone is so thin as to be immaterial in mapping on the quadrangle scales.

The following section of the Colina limestone was measured on the west slope of Colina Ridge in the Tombstone Hills and is offered as the type section of the formation. (See pl. 1.)

Section of the Colina limestone on Colina Ridge, 4,000 feet south of Horquilla Peak

	Thickness (feet)
Epitaph dolomite:	
Dolomite, finely crystalline, black on fresh fracture, weathering dark gray to yellow gray and buff, in beds 6 to 12 in. thick.	
Colina limestone:	
1. Limestone grading upward into dolomite, toward the base dense black limestone weathering blue-gray, mottled with brown-weathering dolomite. The dolomite increases upward and the top of the ledge is all dolomite	8
2. Limestone, black, weathering medium gray, dense, in beds that range from 6 to 12 in. in thickness at base, and become thicker upward. Some 8-ft beds near the top	173
Sill of granitic porphyry (12 feet).	
3. Limestone, black, like unit 2 but in beds 6 to 12 in. thick	13
4. Limestone, like unit 2 but in beds 4 to 20 ft thick; many gastropods. (Coll. 8965)	99
5. Limestone, black (a few beds with minor dolomite that weathers yellowish at the top of the bed), in beds mostly less than 12 in. thick but as much as 4 ft	74
6. Limestone, black, weathering light to medium gray, beds 4 to 12 ft thick, forming a ledge. Many gastropods. (Coll. 8964)	44
7. Limestone, like unit 6 but in beds 2 to 4 ft thick, forming a slope. Contains a little chert in nodules about the size of a walnut. (Coll. 8963)	37
8. Limestone, like unit 6, beds as thick as 10 ft; forms a ledge	51
9. Limestone, black, in beds 1 to 6 in. thick, with a buff sandstone 8 in. thick about 6 ft above the base and with about 8 ft of shaly limestone that forms a slight saddle at the top	30
10. Limestone, very dark-gray, weathers light gray, aphanitic, in beds 2 to 4 ft thick that form a ledge	45
11. Sandstone, limy, weathers brown	1
12. Limestone, black, weathering dark gray, dense, in beds 6 to 12 in. thick, showing a few sandy streaks that emphasize the bedding. A few thin shale and dolomite layers in the lower 40 ft. (Coll. 8962)	58
Total Colina limestone	633
Earp formation:	
Sandstone, pink, limy, weathering dark brown, resting on orange-weathering dolomite. Unit 1 of section of Earp formation measured here	4½

No sections exposing both top and bottom of the Colina limestone are found in the northern part of the area studied by Cooper. A section of the lower part in the Gunnison Hills is as follows:

Section of Colina limestone in Gunnison Hills, 2 miles north of main peak (SE¼ sec. 29, T. 15 S., R. 23 E.)

	Thickness (feet)
Alluvium.	
Unconformity.	
Colina limestone:	
1. Limestone, nearly black, without chert, fine- to medium-grained	47
2. Sandstone, light pinkish-gray, calcareous, thin-bedded (1 to 6 in.), With some interbedded shale	16
3. Limestone, gray, fine-grained, slightly dolomitic, beds 6 to 12 in. thick	18
4. Sandstone, weathering rusty brown, fine-grained; contains some shale in lower part	8
5. Limestone, fine-grained, with many gastropods and echinoid spines; lower part dark gray; upper part weathers to creamy-gray surface wrinkled like elephant hide; upper few feet silty; beds 1 to 2 ft thick	17
6. Limestone, dark-gray to black, fine-grained, without chert; lower part includes a few limestone beds weathering light gray and one 1-ft sandstone bed; cross sections of gastropods, and, rarely, cephalopods seen in some beds. (Coll. 9405A from 40 to 100 ft above base)	179
7. Limestone, fine-grained, weathering to light-gray surface wrinkled like elephant hide	32
8. Sandstone, weathering reddish brown, fine-grained; partly covered	15
9. Limestone, like unit 7, beds 2 to 12 in. thick	11
10. Limestone, dark-gray to blue-black, fine-grained; includes several beds weathering light gray; beds as thick as 2 ft, with some silty partings	98
Thickness of Colina limestone exposed	441
Earp formation:	
Sandstone, weathering reddish brown. Unit 1 of partial section of Earp formation measured here.	

The alluvium which conceals the upper part of the Colina limestone at this locality lies along Walnut Gap (Dragoon quadrangle), a narrow valley running obliquely through the Gunnison Hills nearly parallel to the strike of the beds and along an important fault line. Less than a quarter of a mile northeast, but across Walnut Gap, the lowest beds exposed are assigned to the Colina limestone on the basis of lithology and contained fossils. These beds are, however, overlain by the Scherrer formation rather than by the Epitaph dolomite which overlies the Colina limestone farther south. A section of these somewhat questionable upper Colina strata is as follows:

Section of Colina limestone on west slope of Scherrer Ridge (NE¼ sec. 29, T. 15 S., R. 23 E.)

	Thickness (feet)
Scherrer formation:	
Siltstone, red, in part calcareous, poorly exposed; forms conspicuous bench.	
Depositional contact.	
Colina limestone:	
1. Limestone, fine-grained, fresh fracture light pink, weathered surface tan, with silty laminations and small amount of chert	2½
2. Limestone, fine-grained, slightly dolomitic; fresh fracture dark gray, weathered surface light gray; beds 6 to 12 in. thick	12
3. Limestone, dark-gray, mottled with pink and tan; contains 1/16-in. quartz nodules and also larger nodules of chert	11
4. Covered except for 1 or 2 in. of marl at the base	16
5. Limestone, gray, very fine-grained; beds about 6 in thick	5
6. Limestone, dark-gray to black, fine-grained, in beds 6 in. to 3 ft thick; contains scattered small nodules of chert; pink shale partings between the thinner beds. (Coll. 9406, from lower 80 ft)	144
7. Covered except for two small ledges of fine-grained dolomitic limestone weathering to wrinkled surface which is light gray to tan	37
8. Limestone, light- to dark-gray, fresh fracture pinkish gray, with small amount of chert in upper 15 ft; unit about one-fourth covered	52
9. Limestone, dolomitic, fine-grained, light-gray; more than half of unit covered	48
Thickness of Colina limestone exposed	327½
Lower beds covered.	

EPITAPH DOLOMITE

NAME

The Epitaph dolomite is here named from its exposures on the west side of Epitaph Gulch—the eastern slope of Colina Ridge—where it is well exposed.

DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The Epitaph dolomite is not so broadly exposed as the other formations of the Naco group. It crops out in the Tombstone district, and in the Dragoon Mountains small bodies of the formation are present in the thrust fault zone near Barrett's camp and southeast of Gleeson (Pearce quadrangle). North of Mt. Glen and near Dragoon Peak there are other bodies, and it is present near the Golden Rule mine at the northeast edge of the Dragoon Mountains.

No outcrops of the Epitaph dolomite are known north of the Dragoon Mountains. In the Gunnison Hills, clastic beds of the Scherrer formation rest with depositional contact on rocks which are assigned to the Colina limestone and which are, in fact, indistinguishable from that formation either by lithology or contained fossils. However, the base of these rocks is not exposed and it is possible that the Epitaph dolomite lies below them and is not exposed because of faulting or the vagaries of erosion and distribution of alluvium. If this is true, the Colina-like rocks beneath the Scherrer formation are younger than the Epitaph dolomite and are nowhere exposed in the Dragoon Mountains or Tombstone Hills to the south. If this is not true, either the Epitaph dolomite wedges out toward the north, or the Colina-like beds beneath the Scherrer formation are an unaltered limestone facies of the Epitaph dolomite and the clastic beds of the Scherrer are equivalent to the clastic upper part of the Epitaph at the type locality.

The lower part of the Epitaph dolomite is relatively resistant and commonly forms topographic eminences. The upper part, however, in which considerable shale and thin-bedded limestone occur, is much less resistant to erosion. It commonly forms the foot of dip slopes.

STRATIGRAPHY

The base of the Epitaph dolomite is arbitrarily taken at the base of the first massive dolomite above the zone of partially dolomitized limestone at the top of the Colina limestone. Although the partial dolomitization of the uppermost beds of the Colina limestone is obviously an epigenetic feature, there is no apparent reason to attribute the dolomite of the Epitaph to subsequent metamorphism of an original limestone—it is probably diagenetic. However, even if the dolomite is secondary, it is nevertheless a map unit of stratigraphic value, for the rocks are everywhere markedly different from the underlying Colina limestone. Wherever the upper part of the formation is preserved, it is apparent that the limestone-shale sequence characteristic of this part rests on about equivalent thickness of dolomite. Accordingly, the dolomite is regarded as probably primary or diagenetic and not as metamorphic in origin.

About 200 feet of dolomite form the lowest member of the formation. This dolomite differs notably from all the others in the entire stratigraphic section. It ranges from medium to light gray on fresh fracture and weathers to various shades of gray: light to very dark. One of the most characteristic features of these rocks is the presence of knots of silica—the larger ones with a central cavity—that weather out on the surface. Some of these give suggestions of being silicified fossils but the minute euhedral quartz crystals that commonly coat them obscure the original form of the nuclei. If they do represent fossils they are no longer identifiable. Along with these nodules are much finer granules of silica strewn parallel to the bedding. These are also largely euhedral quartz crystals but may represent secondary enlargement of detrital grains. They commonly weather to brown or tan. All these dolomite beds weather with a rough surface.

Toward the top of this part of the formation partings of red shale occur in the dolomite. The overlying beds are generally poorly exposed sandy limestone or limy sandstone with a higher proportion of maroon shale and much less dolomite. Some of these beds are intraformational breccias; crossbedding, ripple-marks, and other evidences of a shallow-water environment are conspicuous.

The uppermost part of the formation is an assemblage of dolomite, limestone, red shale, and thin sandy layers. A few fossils are present in this member, among them some bellerophontid specimens about the size of a tennis ball.

The upper limit of the formation is a very marked unconformity above which is found the Glance conglomerate or other rocks of Comanche age.

The following section illustrates the lithology of the formation at the type locality. (See pl. 1.)

Section of Epitaph dolomite on the dip slope of Colina Ridge, west of Epitaph Gulch, 1 mile south of Horquilla Peak

	Thickness (feet)
Glance conglomerate:	
Conglomerate, containing boulders and pebbles of dolomite, limestone, granite, rhyolite, and quartzite. About 100 ft exposed. Unconformity—slight angular discordance locally (about 15°), but an erosional surface of a relief exceeding 20 ft in 100 yd.	
Epitaph dolomite:	
1. Limestone, blue, weathering gray, fine-grained, with some beds 2 ft thick but most thinner than 4 in. (Coll. 8515)	103
2. Limestone, gray, massive	9
3. Limestone, blue-gray with a greenish cast, interbedded with maroon-weathering dolomite in beds ordinarily less than 2 in. thick but some as much as 2 ft. The dolomite diminishes upward, giving way to limestone	17
4. Dolomite and shaly limestone, with much sand distributed through them	84
5. Interbedded dolomite, forming ledges, and shaly limestone and limy mudstone, forming saddles. Some of the dolomite and mudstone are sandy. The shaly parts are maroon. The tops of many of the ledges are sedimentary breccias. About one-third of the unit is dolomite	75½
6. Dolomite, massive, finely crystalline, reddish-gray on fresh fracture, weathering to a somber brownish gray, forms a strong ledge and dip slope on a prominent sharp spur of the ridge	13½
7. Concealed; probably maroon shale	6
8. Dolomite, coarsely crystalline, pink on fresh fracture, weathering to a yellow-gray; forms a massive ledge	25
9. Poorly exposed shale and dolomite, alternating	10
10. Dolomite, massive, slightly sandy, red-brown on fresh fracture, weathering buff	8
11. Dolomitic breccia, sedimentary	2
12. Concealed; probably shale and thin dolomite beds	26
13. Dolomite, red-brown on fresh fracture, weathering light cream to buff	6
14. Mudstone, red, containing fragments of dolomite, poorly exposed	33
15. Dolomite, cream-colored, with cracks in upper surface filled during sedimentation by muddy breccia like unit 14	5

Section of Epitaph dolomite on the dip slope of Colina Ridge, west of Epitaph Gulch, 1 mile south of Horquilla Peak—Con.

Epitaph dolomite—Continued	Thickness (feet)
16. Concealed	8
17. Limestone, sandy, bright-red on fresh fracture, weathering to brown and buff; massive	4
18. Poorly exposed, soft sandy red limestone or limy sandstone, with some thin beds of dolomite and maroon shale. Forms prominent saddle on ridge. (Coll. 8966)	74
19. Dolomite, buff-weathering, in beds 4 to 6 in. thick, with thin shaly partings	58
20. Sandstone, yellow-weathering, poorly exposed	11
21. Dolomite, finely crystalline, black to dark-gray on fresh fracture, weathers dark gray, yellow-gray, pale gray, and buff, with local thin streaks of brown-weathering quartz grains. Beds from 6 in. to 2 ft thick, mostly less than 1 ft. Many siliceous geodes and quartzose knots from ¼ in. to 2 in. in diameter weather out on the surface	205
Total Epitaph dolomite	783
Colina limestone:	
Limestone, mottled with brown-weathering dolomite that becomes more abundant upward. The transition to massive dolomite here occurs in 4 feet, stratigraphically.	

PROBLEM OF STATIGRAPHIC INTERPRETATION

On the ridge west of the Golden Rule mine at the northern end of the Dragoon Mountains a thick section of the Epitaph dolomite overlies the Colina limestone. Although the upper boundary of the formation is faulted, about 750 feet of beds are referable to the Epitaph. This section was not measured in detail but its gross lithologic features are indicated on plate 1, from which it can be seen that about 380 ft of the basal part of the formation is dolomite. As this locality is only about 5 miles from Scherrer Ridge, where the beds referred to the Colina are overlain by the sands of the Scherrer formation, the correlation of beds between these localities poses a difficult problem. Three possible interpretations are:

1. The Epitaph dolomite has been eroded in the Gunnison Hills area and the Scherrer formation is an overlapping formation younger than the Epitaph. This interpretation requires an unconformity at the base of the Scherrer formation. The base of this formation is well exposed on Scherrer Ridge but no evidence of angular or erosional unconformity was noted.

2. The Epitaph dolomite is equivalent to beds in the concealed interval between the lower and upper parts of the Colina limestone of the Gunnison Hills. Lack of exposures of the Epitaph in the Gunnison Hills would probably require a change in lithology or downfaulting of the ridge-forming part of the formation.

3. The lower part of the Epitaph is the dolomitized equivalent of beds referred to the Colina limestone in the Gunnison Hills and the upper part of the Epitaph is equivalent to part or all of the Scherrer formation. This would require a more rapid change of facies in the Epitaph than is indicated in the Tombstone Hills-Dragoon Mountains area.

The determination of which of the three hypotheses is correct must await more extensive regional studies or more precise dating of particular beds by their fossils or other evidence. The correlation lines on plate 1 are drawn in the most convenient way to separate the formations and do not mean that the writers favor the hypothesis that the Scherrer formation is an overlapping younger formation. In fact this is regarded as a somewhat less likely interpretation than either of the other hypotheses given.

THICKNESS

The pre-Comanche unconformity, although locally marked by slight angular discordance, is elsewhere a record of major deformation. The Paleozoic and older rocks were highly faulted, locally invaded by large igneous masses, and then deeply eroded. As a result, the Epitaph dolomite was eroded in larger measure than any of the lower formations and its preserved thickness varies greatly. That this variation is erosional rather than depositional is shown by the presence of several hundred feet of Epitaph dolomite at the northeast edge of the Dragoon Mountains near the Golden Rule mine.

Doubtless the sporadic and sparse distribution of the formation in the Dragoon Mountains is in large part due to the pre-Cretaceous erosion as well as to the post-Comanche thrust-faults.

CONDITIONS OF DEPOSITION

The lower third of the Epitaph dolomite contains little terrigenous sediment. Whether the dolomitization resulted from slow deposition in shallow waters, as has been postulated for certain other dolomites (Nolan 1935, p. 22–23) and is suggested by features indicative of shallow water in higher parts of the formation, cannot be decided without detailed investigation. The sedimentary breccias, crossbedding, ripple-marks, and high proportion of sand and shale all suggest strongly that the upper part of the formation was laid down in shallow water. The marine fauna sparsely represented in the upper part of the Epitaph dolomite shows it to be marine, as the lower part almost certainly is too.

SCHERRER FORMATION

NAME

The Scherrer formation is here named from its exposures on Scherrer Ridge which is that part of the Gunnison Hills lying northeast of Walnut Gap (Dragoon quadrangle).

DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The only outcrops of the Scherrer formation in the area of this report are along Scherrer Ridge for a distance of a little less than 2 miles. The quartzitic sandstone members which make up more than half the formation are resistant rocks and form the highest part of the ridge. The siltstone member at the base is nonresistant and forms a conspicuous bench at most places. The central limestone member forms dip slopes and topographic sags.

STRATIGRAPHY

Within the limited area in which the Scherrer formation is now known, the formation is distinctive lithologically and is characterized by a fixed sequence of members. The base is an easily identified plane beneath a bright red siltstone member about 65 feet thick, and rests directly on the relatively uniform dark-gray to black limestone assigned to the Colina. Above the siltstone there are, in turn, about 30 feet of fine-grained gray limestone, 270 feet of sandstone containing a few beds of limestone in the lower part, 165 feet of gray limestone, and 150 feet of sandstone.

The sandstone is nearly white on fresh fracture but generally weathers rusty brown. The beds are 2 to 18 inches thick. A few are crossbedded and ripple-marked. Exposed surfaces are commonly hardened to quartzite and yield much angular rubble. Thick quartzitic sandstone members like those in the Scherrer formation are not known in other formations of the Naco group.

The thick limestone member between the two similar sandstone members is a conspicuous feature of the formation. The limestone is fine grained, relatively thin bedded, and in part somewhat dolomitic. The prevalent color is light gray. Nodules or rosettes of white quartz as much as a quarter of an inch in diameter are found in the lower part. Rusty brown chert nodules are found sparingly throughout and are abundant in a few beds in the middle and upper part. Well-preserved echinoid spines, which are of several obviously different types, are the only fossils generally seen. Although echinoid spines are found in other formations of the Naco group, no other formation in the area even remotely approaches the limestone of the Scherrer formation in the relative abundance, diversity of form, and perfection of preservation of this easily recognized fossil.

Although the contact between the Scherrer formation and the underlying Colina limestone is knife-sharp and obviously represents a great change in conditions of deposition, no evidence of either angular or erosional unconformity was detected. The very top of the Colina limestone is continuously exposed for long distances because of the inferior resistance of the basal siltstone of the Scherrer. It seems to follow the same bedding plane at all places.

The following section, shown graphically on plate 1, is presented as the type section of the Scherrer formation.

TYPE SECTION

Section of Scherrer formation on Scherrer Ridge and Concha Ridge, Gunnison Hills. Top of section measured along crest of Concha Ridge (SW ¼ NW ¼ sec. 28, T. 15 S., R. 23 E.)

	Thickness (feet)
Concha limestone:	
Limestone, dark-gray, fine-grained; at bottom of saddle. Unit 5, p. 29.	
Scherrer formation:	
1. Sandstone, weathering rusty brown, fine-grained, quartzitic; beds 1 to 10 in. thick; sand grains well rounded	6
2. Covered	9
3. Sandstone, like unit 1	15
4. Covered	11
5. Sandstone, like unit 1	115
6. Limestone, dark-gray, medium-grained, becoming fine-grained and pinkish at top; very scarce chert; beds as thick as 1 ft	11
7. Limestone, light-tan to white, fine-grained, with irregular chert nodules which weather brown	5
8. Limestone, light-gray to pinkish, fine-grained; contains small vugs lined with calcite crystals; beds as thick as 1½ ft	13
9. Limestone, red, silty; beds as thick as 3 in.; partly covered	25
10. Covered	11
11. Limestone, light-gray, with lavender cast, fine-grained, with abundant well-preserved echinoid spines; contains brown-weathering chert nodules (coll. 9407)	18
12. Limestone, light-gray to light-tan, with brown-weathering chert nodules; beds as thick as 1 ft	22
13. Limestone, light creamy-gray to dark-gray, slightly dolomitic, fine-grained; weathers to pitted surface; contains scarce 1- to 3-in. brown-weathering chert nodules; lower few feet contains ¼-in. nodules of white quartz; beds as thick as 1 ft	60
Because of faults and cover in the lower part of the section at this locality, lower beds were measured about 1,750 ft to the northwest on west face of Scherrer Ridge (NE¼NE¼ sec. 29, T. 15 S., R. 23 E.).	
14. Sandstone, white to rusty-brown, fine-grained, in beds 2 to 12 in. thick; in places crossbedded; cementing matter slightly limy but surface commonly hardened to quartzite	148
15. Limestone, dolomitic, dark-gray, fine-grained, weathering to rough surface; lower surface of bed irregular	3
16. Sandstone, like unit 14	15
17. Limestone, gray, fine-grained, weathering to rough surface; lower surface irregular	11
18. Sandstone, like unit 14	95
19. Limestone, light-gray with some pink and blue mottling, fine-grained; beds as thick as 1 ft	29

Section of Scherrer formation on Scherrer Ridge and Concha Ridge, Gunnison Hills. Top of section measured along crest of Concha Ridge—Continued

	Thickness (feet)
Scherrer formation—Continued	
20. Siltstone, red to pinkish, limy, in thin beds; largely covered and forms bench	65
Thickness of Scherrer formation	687
Colina limestone:	
Limestone, pinkish-tan, with laminations of silt and small nodules and bands of chert (bed 2 ft thick; same as unit 1, p. 25 but across fault from that locality).	

The error involved in piecing together the foregoing section is thought to be negligible because of the sharp lithologic break at the plane correlated. Above the plane is limestone roughly 150 feet thick (units 6 to 13 inclusive); below it, is sandstone roughly 270 feet thick (units 14 to 18 inclusive). Enough beds were measured below unit 13 at the first locality and above unit 14 at the second locality to remove any reasonable doubt of the validity of the correlation between the two parts of the section.

THICKNESS

The thickness of the Scherrer formation measured, 687 feet, is typical for the small area in which the formation is now known except where the upper part was eroded in pre-Cretaceous time and the top is marked by the unconformable Glance conglomerate. Although the angular discordance between the Cretaceous and the older rocks is small, the pre-Cretaceous unconformity represents a time of important faulting and deep erosion. The Glance conglomerate abruptly overlaps the older beds. Thus between the two parts of the type section of the Scherrer formation, a distance of only 1,750 feet, the Glance conglomerate fills an old valley which cuts down within several hundred feet of the bottom of the Scherrer formation. Pre-Cretaceous erosion may be the reason that the Scherrer formation is not found in the Dragoon Mountains-Tombstone area to the south.

CONCHA LIMESTONE

NAME

The Concha limestone is here named for Concha Ridge, a conspicuous transverse spur of Scherrer Ridge in the Gunnison Hills.

DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The Concha limestone crops out at intervals along Scherrer Ridge but is not exposed elsewhere in the area of this report. On the whole, the formation is resistant to erosion and forms summits that are almost as high as those formed by the sandstone members of the Scherrer formation. However, the calcareous sandstone at the base of the Concha is nonresistant and forms dip slopes and small saddles.

STRATIGRAPHY

The lower part of the Concha limestone consists, for the most part, of fine-grained calcareous sandstone which was assigned to the Concha limestone rather than to the Scherrer formation because it grades into the limestone above and differs from the sandstone of the Scherrer formation in being much more calcareous, and gray rather than rusty brown on weathered surfaces. It has no tendency to become silicified to quartzite on the outside but decomposes on exposure into friable rounded pebbles and cobbles. On casual inspection it might be mistaken for limestone.

Above the basal sandy beds which are probably nowhere more than 50 feet thick, the formation consists of gray, medium-grained limestone which is highly fossiliferous and contains very abundant irregular nodules of light-colored chert weathering pale brown. Probably the most common fossils are productid brachiopods as much as 3 inches across and 2 inches high, substantially larger than those found in the older formations.

The following section, a continuation of the one on page 28, is presented as the type section of the Concha limestone. It is shown graphically on plate 1.

TYPE SECTION

Section of Concha limestone on east end of Concha Ridge, Gunnison Hills (NW¼ sec. 28, T. 15 S., R. 23 E.)

	Thickness (feet)
Glance conglomerate:	
Conglomerate, with limestone fragments as much as 8 inches in diameter and smaller chert fragments; fragments rounded and closely packed together but not well sorted; tightly cemented.	
Unconformity.	
Concha limestone:	
1. Limestone, gray, medium-grained, with very abundant irregular and rounded nodules of light-colored chert weathering pale brown; very fossiliferous. (Coll. 9407C from 30 to 50 ft above base; coll. 9407B, from 20 to 30 ft above base; coll. 9407A, from 0 to 20 ft above base.)	87
2. Limestone, light gray to pinkish-gray, fine-grained, with a little chert	6
3. Limestone, sandy, dark-gray, with a little chert	4
4. Sandstone, gray, calcareous, fine-grained; sand grains more or less angular; rock weathers into friable rounded pebbles and cobbles	31
5. Limestone, dark-gray, fine-grained, at bottom of saddle	1½
Thickness of Concha limestone	129½
Scherrer formation:	
Sandstone, fine-grained, quartzitic, weathering rusty brown. Unit 1, p. 28.	

THICKNESS

The Concha limestone differs abruptly in thickness from place to place because at its top is an unconformity of major importance. The thickness measured at the type section, 129½ feet, is probably not the maximum, even on Scherrer Ridge; but the places where greater thicknesses are probably present are too much faulted and too poorly exposed for stratigraphic measurement. The unconformity at the top of the formation is not marked by much angular discordance but is a surface of considerable relief. At one place on Scherrer ridge a pre-Cretaceous valley, now filled by the Glance conglomerate, cuts completely through the Concha limestone and through a large part of the Scherrer formation. In another valley andesitic rocks rest unconformably on the Scherrer formation and Concha limestone and are overlain unconformably by the Glance conglomerate. These volcanic rocks, which evidently represent a remnant of a more extensive blanket, are presumed to be of Triassic or Jurassic age.

AGE AND CORRELATION OF FORMATIONS OF THE NACO GROUP

By James Steele Williams

GENERAL DISCUSSION

As stated elsewhere in this report, faunas of two ages were recognized by Girty in the Naco formation (here called group) when this formation was established by Ransome in 1904. The older of these faunas was referred to by Girty as of early Pennsylvanian age. The younger fauna was said by him to be related to that of the "limestones of the Hueco Mountains of Western Texas" and to have some forms in common with the "Aubrey limestone" (now Kaibab) of the Grand Canyon region and the "Permo-Carboniferous" of California (probably McCloud limestone of present usage). At that time, Girty had a tendency to classify all Pennsylvanian strata of Des Moines or older age as "early Pennsylvanian," a tendency that the writer prefers to follow at present in the West. Under such usage the Pennsylvanian rocks would be divided into two rather than the three to five divisions that have been proposed at one or another times. The younger fauna recognized by Girty in the Naco is probably mainly that of the Colina of this report. Elements of it may be distributed (in this paper) among about five formations that are described primarily on the basis of lithology.

The age of the Hueco fauna with which Girty in 1904 compared his late Pennsylvanian faunas of the Naco is now in dispute, partly because of philosophical differences regarding the location of the Pennsylvanian-Permian boundary in the United States and of its equivalent abroad. The U. S. Geological Survey currently classifies the Hueco fauna as of Permian(?) age and correlates it with the Wolfcamp formation of the west Texas section, which is also designated as Permian(?). Some geologists in this country and many foreign geologists believe as Girty did that the Hueco and equivalent beds would be best classified as Carboniferous, whereas others believe that it would be better to refer to them as Permian.

Within the last several years both Robert E. King (1931, p. 16, 17) and Philip B. King (1942, p. 556-560) have suggested that the upper part of the Hueco may be of Leonard or equivalent age and thus the equivalent of beds widely recognized to be of Permian age. When Girty correlated the younger fauna of the Naco in general terms with the Hueco, he was astonished at the resemblances between the gastropods of the two faunas; but because of the occurrences of *Productus ivesi* (*Dictyoclostus ivesi bassi* of this paper) and several other brachiopods of Kaibab age and facies, he remarked on the seeming conflict between correlative evidence of the gastropods and that of the brachiopods. Recent studies of the gastropods of the Hueco and related faunas by J. Brookes Knight and new data on stratigraphic paleontology obtained during these studies have shown that some of the Hueco-type gastropods extend into beds that others have said are of Leonard age or are represented in those beds by closely related species or genera not heretofore known to occur in them.

There are two principal marine sections with which the upper Naco rocks of Arizona could be correlated. One of these is the Grand Canyon section of northern Arizona. This is not far from the Tombstone section, as the crow flies, but it differs considerably in facies from the section in southeastern Arizona. The other section is the one usually termed the west Texas Permian section. This section actually includes a considerable area in New Mexico. Many geologists consider it the type Permian section for the Southwest, if not for an even greater area. Reefs and other unusual facies have long been known to occur there, and many attempts have been made to work out stratigraphic interpretations that give adequate weight to all the divergent stratigraphic, paleontologic, and paleoecologic factors. Most of the early work was done by members of the U. S. Geological Survey and of Texas State organizations, but during the past 20 years geologists and paleontologists from many other institutions and organizations have taken more and more prominent parts.[3] Paleontologists, drawn by the increased dissemination of the knowledge of the fine material that could be had by etching, have collected

[3] So many organizations and individuals have taken part that it would be impossible to list them all. Similarly, the literature is so voluminous that it cannot all be given here. To compile a bibliography, the "Bibliography of North American geology" should be consulted.

many tons of material. One of several participating institutions, and perhaps the leader in recent years, has been the U. S. National Museum.[4]

As these larger collections are made, it is being shown, as one would expect, that published ranges of many forms were not correct because previous collecting had not been nearly enough complete. Some "index" fossils either must no longer be considered "index" fossils of the stratigraphic units to which they were thought to be confined, or formation boundaries as previously established must be changed. Opinions strongly differ at present about which is the better course to pursue. This situation makes difficult the correlation of the formations of the Naco group with those of the west Texas Permian. Also, much of the new information gained from the recently made large collections from west Texas is as yet unpublished and there is still a dearth of good collections of well-preserved and definitely identifiable fossils in certain formations of the upper Naco group. Positive correlations of formations laid down under different ecological conditions and in different areas are never easy to make. Too commonly, larger collections of fossils and more detailed studies show more intergradation than differences among faunas from adjacent formations of somewhat comparable ecologic backgrounds. Most paleontologists know that all correlations made are made only provisionally, and none is better than the information available at the time it is made. As new information becomes available correlations are subject to change. It is with full realization of these limitations and others that the correlation of the units of the upper Naco group with those in the west Texas Permian section is undertaken.

The Tombstone section could have been compared with units in sections in New Mexico, but it was not done because paleontologic work in much of New Mexico has not kept pace with the stratigraphic work, and the writers felt that the stratigraphic ranges of forms of Pennsylvanian and post-Pennsylvanian Paleozoic age were not well enough known to them in terms of stratigraphic units now in current use to permit detailed correlations of much value to be made. The Geological Survey has many collections from New Mexico, and after these are studied, they may, when augmented by studies by other paleontologists, provide a more substantial basis than now exists for use in faunal correlation.

Some of the faunas in the upper Naco obviously are Kaibab faunas, and general correlations can be made with the Kaibab and with other formations in Arizona. Correlation with the Kaibab does not, however, assure correlation with the west Texas section. Many have interpreted the fauna represented by fossils in beds older than the so-called *Bellerophon* limestone (Reeside and Bassler, 1922, p. 56), which is at the top of the Kaibab, to be of Leonard age, for these beds correlate with the fauna in the west Texas Permian section generally attributed to the Leonard. Others regard the fauna of these beds of the Kaibab as of Word age.[5]

[4] Many other institutions and individuals have made significant studies and important collections. The authors regret that it is impossible to list them all.

[5] Newell, N. D., 1948, Key Permian section, Confusion Range, western Utah: Geol. Soc. America Bull., v. 59, no. 10, p. 1054; and Wagner, O. E., 1932, The paleontology and stratigraphy of the Kaibab limestone: [abs. of thesis] Univ. of Illinois.

HORQUILLA LIMESTONE

The Horquilla limestone has a large and varied fauna. Brachiopods and fusulinids are the most important elements insofar as numbers and age significance are concerned. Crinoid stem-joints are also common, but no identifiable calices were found during this study. Corals and, to a somewhat lesser extent, bryozoa are a significant element of the fauna. Pelecypods and gastropods are neither common nor significant as age determinants. The trilobites are also few in number and also happen to lack definite age significance. An occasional echinoid spine is seen, as is an occasional indeterminate fish bone.

COLLECTIONS FROM TOMBSTONE HILLS

Collections from or near stratigraphic section of the Horquilla limestone measured on spur east of Horquilla Peak, Tombstone Hills (see p. 17).

Collection ☆8484 (from beds that have been eroded from top of stratigraphic section on p. 17 but that occur in an area nearby).
- *Neospirifer dunbari* King
- sp. A
- *Composita subtilita* (Hall)
- *Dictyoclostus coloradoensis* (Girty), n. var. A
- *Echinoconchus semipunctatus knighti* Dunbar and Condra?
- *Linoproductus platyumbonus* Dunbar and Condra?

Collection ☆8483 (from a zone below that of coll. ☆8484 but from beds that have been eroded from top of stratigraphic section described on p. 17 and that occur in an area nearby).
- *Lophophyllidium* sp. C.?
- Crinoid stems
- Fistuliporoid bryozoan, incrusting type 1
- *Rhabdomeson* sp.
- *Rhomboporella?*
- *Wellerella?* sp. indet.
- *Neospirifer dunbari* King?
- *Derbyia?* sp. indet.
- *Linoproductus* sp. undet.
- *Reticulariina?* sp. undet.
- Bone? fragment, probably fish

Collection ☆8482 (from a zone below that of coll. ☆8483, but from beds that have been eroded from top of stratigraphic section described on p. 17 but that occur in an area nearby).
- Crinoid stems
- *Neospirifer dunbari* King
- *Phricodothyris?* sp. undet.
- *Composita* sp. indet.
- *Dictyoclostus coloradoensis* (Girty), n. var. A.
- *Linoproductus prattenianus* (Norwood and Pratten)

Rhynchopora? sp. undet.
Dielasma bovidens (Morton)?
Gastropod, high-spired, indet.

Collection ☆8487 (from a zone in an area nearby thought to be 25 to 30 feet above zone of coll. 8479).
Caninia sp. A.?
? cf. sp. B
Dibunophyllum? sp.
Lophophyllidium? sp. C?
Neospirifer dunbari King
Cleiothyridina orbicularis (McChesney)
Composita subtilita (Hall)
Dictyoclostus coloradoensis (Girty), n. var. A.
Juresania nebrascensis (Owen)
Echinoconchus semipunctatus (Shepard)
Echinoconchus, n. sp. A.
Marginifera splendens (Norwood and Pratten)
Linoproductus prattenianus (Norwood and Pratten)
"*Productus*"? sp. indet.
Reticulariina? sp. undet.
Dielasma bovidens (Morton)?

Collection 8479 (from unit 1 of stratigraphic section on p. 17).
Echinocrinus sp.
Spirifer occidentalis Girty?
rockymontanus Marcou, n. var. A.
sp. undet.
Phricodothyris perplexa (McChesney)?
Composita subtilita (Hall)
Pustula? sp. undet.
Euomphalid gastropod, gen. and sp. undet.

Collection ☆8480 (from a zone in an area nearby thought to be about the same as the zone of coll. 8479).
Empodesma? sp.
Zaphrentoid coral, probably n. gen.
Caninia sp. A.
Spirifer rockymontanus Marcou, n. var. A.
Phricodothyris perplexa (McChesney)
Crurithyris? planoconvexa (Shumard)
Composita sp. indet.
Marginifera? sp. undet.
Rhipidomella? carbonaria (Swallow)?
Hustedia mormoni (Marcou)
Dielasma? sp.

Collection 8934 (from unit 8 of stratigraphic section on p. 17).
Neospirifer dunbari King
Phricodothyris? sp. undet.
Composita subtilita (Hall)
Dictyoclostus coloradoensis (Girty), n. var. A.
Juresania nebrascensis (Owen)
Marginifera? sp. undet.
Linoproductus prattenianus (Norwood and Pratten)
sp. undet.

Collection 8933 (from unit 16 of stratigraphic section on p. 17).
Rhombotrypella n. sp.
Fenestella sp. indet.
Rhomboporella, n. sp. B
Orbiculoidea capuliformis (McChesney)
Derbyia? cf. *D. crassa* (Meek and Hayden)?
Dictyoclostus americanus Dunbar and Condra
coloradoensis (Girty), n. var. A
Linoproductus prattenianus (Norwood and Pratten)
sp. undet.
"*Producius*," n. sp. A
Rhynchopora? sp. undet.

Collection 8932 (from unit 17 of stratigraphic section described on p. 17.
Caninia sp. A.
? sp. E.
Crinoid stems
Fistuliporoid bryozoan, incrusting type.
Chainodictyon sp.
Fenestella sp. D
Rhomboporoid bryozoan, gen. indet.
Prismopora sp. undet.
Spirifer rockymontanus Marcou
Neospirifer dunbari King
sp. undet.
Phricodothyris perplexa (McChesney)
Derbyia? cf. *D. crassa* (Meek and Hayden)
Chonetes granulifer Owen
Mesolobus striatus (Weller and McGehee)
sp. indet.
Dictyoclostus coloradoensis (Girty), n. var. A.
Echinoconchus semipunctatus knighti Dunbar and Condra?
Pustula? sp. undet.
Linoproductus prattenianus (Norwood and Pratten)
Schizophoria? sp. undet.
Punctospirifer kentuckyensis (Shumard)

Collection 8931 (from top of unit 18 of stratigraphic section described on p. 17).
Spirifer rockymontanus Marcou, n. var. A.
Composita subtilita (Hall)
Derbyia? cf. *D. crassa* (Meek and Hayden)
Dictyoclostus coloradoensis (Girty), n. var. A?
Juresania nebrascensis (Owen)

Collection 8387 (from same zone and stratigraphic section as coll. 8931)
Caninia sp. A.
sp. B.

Collection 8386 (from middle of unit 18 of stratigraphic section described on p. 17).
Lophophyllidium sp. B.
Spirifer occidentalis? Girty
rockymontanus Marcou, n. var. A.
Composita ovata Mather
Dictyoclostus morrowensis? Mather
Buxtonia? sp. undet.
"*Productus*"? sp. undet.
Punctospirifer? sp. undet.
Bellerophontid gastropod, gen. and sp. undet.
Bone fragments, probably fish.

Collection 8385 (from unit 19 of stratigraphic section described on p. 17 in lower 52 feet of Horquilla).
Spirifer rockymontanus opimus Hall
Composita sp. indet.
Mesolobus striatus Weller and McGehee
sp. indet.
Marginifera? sp. undet.
Rhynchopora magnicosta Mather?
Punctospirifer kentuckyensis (Shumard)

Collection 8930 (from same zone and locality as coll. 8385).
Stereostylus? sp. A.
Crinoid stems
Rhomboporella, n. sp. C.?
Spirifer occidentalis Girty?
rockymontanus Marcou, n. var. A.
Composita subtilita (Hall)?
Dictyoclostus coloradoensis (Girty), n. var. A.?

Marginifera splendens (Norwood and Pratten)?
Linoproductus gallatinensis (Girty)
prattenianus (Norwood and Pratten)
Punctospirifer kentuckyensis (Shumard)
Reticulariina? sp. undet.
Pelecypod, 1 sp. undet.

COLLECTIONS FROM GUNNISON HILLS

Collections from or near stratigraphic section of Horquilla limestone on main ridge of Gunnison Hills, ¼ mile north of main peak, sec. 4, T. 16 S., R. 23 E. (see p. 18).

Collection 9402F (from unit 1 of stratigraphic section described on p. 18 in upper 37 feet of Horquilla formation).
Calcitornellid Foraminifera
Triticites sp. indet.
Crinoid stems

Collection ☆9403 (from zone in a section nearby that is thought to be about equal to zone of unit 1 in stratigraphic section described on p. 18).
Triticites pygmaeus Dunbar and Condra
sp.
Multithecopora? sp. B.
Bellerophontid gastropod, gen. indet.
Pleurotomarian gastropod, n. gen.?

Collection 9402E (from unit 3 of stratigraphic section described on p. 18).
Triticites sp.
Syringopora sp. C?
Multithecopora? sp. B

Collection 9402D (from unit 3 of stratigraphic section described on p. 18, about 115 feet below coll. 9402E).
Syringopora sp. B

Collection 9402C (from unit 4 of stratigraphic section described on p. 18).
Triticites sp.
Crinoid stems
Punctospirifer kentuckyensis (Shumard)
Dielasma bovidens (Morton)

Collection ☆9195 (from zone in section nearby thought to be stratigraphically between zones of colls. 9402B and 9402C).
Syringopora sp. B

Collection 9402B (from unit 7 of stratigraphic section on p. 18).
Phricodothyris? sp. undet.
Composita subtilita (Hall)?
Dictyoclostus cf. *D. coloradoensis* (Girty)
Marginifera wabashensis (Norwood and Pratten)?
Hustedia mormoni (Marcou)

Collection 9402A (from unit 7 of stratigraphic section on p. 18, about 80 feet below coll. 9402B).
Caninia sp. A.
Syringoporoid coral, gen. indet.
Composita subtilita (Hall)
Echinoconchus? *semipunctatus* (Shepard)?
Myalina sp. undet.

Collection ☆9194 (from zone in an area nearby thought to be about 240 feet stratigraphically below zone of coll. 9402A and about 50 feet above zone of coll. 9402).
Fusulina knighti Dunbar and Henbest
Fenestella sp. undet.
Rhomboporella sp. undet.
Prismopora sp. undet.
Spirifer rockymontanus Marcou, n. var.

Collection 9402 (from unit 9 of stratigraphic section described on p. 18).
Wedekindellina excentrica (Roth and Skinner)
Fusulina distenta (Roth and Skinner); possibly *F. novamexicana* (Needham)
Crinoid stems

Collection ☆9191 (from zone in an area nearby thought to be about 240 feet stratigraphically below zone of coll. 9402 and about 200 feet above base of formation).
Wedekindellina sp. earlier than *W. euthysepta* (Henbest)
Fusulina or *Fusulinella* sp.
Fusulina (early form)
Other smaller Foraminifera

Collection ☆9190 (from zone in an area nearby thought to be less than 10 feet above base of formation).
Fusulinella cf. *F. iowensis* Thompson
Bradyina sp.
Crinoid stems
Spirifer rockymontanus opimus Hall
sp. undet.
Composita subtilita (Hall)
Derbyia? cf. *D. robusta* Hall
? sp. undet.
Linoproductus cf. *L. tenuicostus* (Hall)
"*Productus*" s. l., sp. undet.
Aviculopecten sp. undet.
Gastropods, undet.
Kaskia chesterensis Weller?

COLLECTIONS FROM OTHER LOCALITIES

Collections of Horquilla fossils not from measured section described in this report. (For locality data, see register of localities, p. 43.)

Collections ☆8946 (stratigraphic position uncertain, thought to be from middle or lower part of Horquilla).
Ammodiscus? sp.
Endothyra sp.
Millerella? sp.
Fusulinella? *serotina* Thompson
Wedekindellina euthysepta (Henbest)
perforata (Roth and Skinner) (or *Fusulinella*?)
Fusulina aff. *F. leei* Skinner
Textrataxis sp.
Caninia sp. A.
Multithecopora? sp. indet.
Spirifer rockymontanus Marcou, n. var. A.
Neospirifer sp. undet.
Dictyoclostus coloradoensis (Girty), n. var. A.?
Marginifera? sp. undet.
Linoproductus sp. undet.
"*Productus*" sp. undet.
Rhynchopora? sp. undet.
Punctospirifer kentuckyensis (Shumard)
Hustedia mormoni (Marcou)

Collection ☆8948 (stratigraphic position uncertain, thought to be from middle or lower part of Horquilla).
Caninia sp. D.
sp. indet.
Michelinia? sp. indet.
Multithecopora? sp. B
Crinoid stems
Prismopora? sp. undet.
Mesolobus sp. undet.
Dictyoclostus coloradoensis (Girty), n. var. A
Dictyoclostus? sp. undet.

CHARACTER AND AGE OF THE FAUNA

Brachiopods, corals, and Foraminifera all suggest that the Horquilla limestone as mapped contains beds ranging in age from post-Morrow Pennsylvanian to middle late Pennsylvanian. It is possible that beds of Morrow age may be present, but if so, they are not of Morrow facies and genera of fossils such as *Mesolobus* have longer ranges here than in the area where typical Morrow facies is exposed. This genus is unknown in the typical Morrow. A few species typical of Morrow age have been tentatively identified but for the most part these are in collections having other fossils that are typically of Lampasas[6] and Des Moines age or they occur stratigraphically above such collections. Another possibility is that the identifications of the Morrow forms, being based on incomplete material and but tentatively made, may be in error. Still another is that the ranges of the Morrow fossils found here may represent extensions of their characteristic ranges.

No attempt is made to separate a Lampasas faunal zone from a Des Moines faunal zone, because it appears to the writer that the criteria in the literature for such a separation have not been adequately tested on a wide geographic basis or actually do not hold. This is true especially of the larger invertebrate fossils in the Western United States. The oldest part of the Horquilla is either Lampasas or Des Moines in age if one can distinguish between them. Representative collections from this age zone are nos. 8932, 8385, and 8946.

Of the brachiopods, this Lampasas and Des Moines part of the Horquilla is characterized by such forms as Spirifers of the *S. rockymontanus* type and its varieties, *Spirifer occidentalis*, and *Mesolobus* species and varieties. *Dictyoclostus coloradoensis* Girty, n. var. A. and *Neospirifer dunbari* King are also common, but both range into younger beds. The bryozoan genus *Prismopora* is locally especially distinctive. The form tentatively identified as *Linoproductus platyumbonus* Dunbar and Condra appears to be here representative of post-Des Moines beds, as it is elsewhere. *Dictyoclostus americanus* Dunbar and Condra, unlike the interpretation given it in its type locality, is here associated in stratigraphic sequence with fossils that suggest it possibly extends down into beds of Des Moines age.

Henbest (memorandum, June 24, 1947) has discussed the age significance of fusulinids in collections from the stratigraphic section of the Horquilla of the Gunnison Hills. He describes the *Fusulinella* in collection 9190 as indicating "lower middle (Atoka) Pennsylvanian age." Of the fusulinids in collection 9191, he says:

> This collection contains *Wedekindellina* of a type seemingly older than *W. euthysepta* (Henbest), *Fusulina* or *Fusulinella* sp. and an early form of *Fusulina*, and various smaller Foraminifera These indicate early Des Moines age. These forms belong to the *Wedekindellina-Fusulina* fauna that characterize the Des Moines in many different parts of the world. This fauna indicates a correlation with the middle or lower middle part of the Hermosa and with a part of the Sandia formation locally in New Mexico.

The fusulinids in collection 9402 are described by Henbest as follows:

> This small sample is a part of the most widely distributed foraminiferal fauna in the Pennsylvanian in the world. It characterizes the McCoy fauna of Colorado (Roth and Skinner, 1930), the middle and upper parts of the Hermosa, the middle part of the Carbondale of Illinois, and other formations that belong near the middle of the lower half of the Des Moines* * *.

Of the fusulinids of collection 9194, Henbest says:

> This sample contains *Fusulina knighti* Dunbar and Henbest, 1943. This species has a rather generalized morphology, and because it is difficult to distinguish definitely, its range within the Des Moines is not clearly known. Des Moines age is definitely indicated and the middle part of the Des Moines is suggested.

Collection 9402C contains a species of *Triticites* that "* * * indicates Missouri age or at the highest, lower Virgil age." Collection 9402E contains "* * * a species of *Triticites* that represents a stage of evolution commonly displayed near the middle of the Virgil. I doubt that this is so old as Missouri, but might possibly be as young as the basal Big Blue."

The fusulinids of collection 9403 consist of a *Triticites pygmaeus* Dunbar and Condra, 1927, and perhaps another species of *Triticites*. Henbest writes that *Triticites pygmaeus* characterizes a part of the Kansas City formation—Missouri group of present Geological Survey classification—in Kansas, Missouri, and Nebraska. "I have observed this species in Wyoming and New Mexico," he continues. "I know of no instance of its occurring above the lower Missouri * * *."

Collection 9402F is from beds near the top of Horquilla but at approximately the same stratigraphic zone as collection 9403. Of the fusulinids in this collection, Henbest says:

> This specimen of metamorphosed limestone contains calsitornellid Foraminifera, porcellaneous algaloid remains, and a single fragment of a species of *Triticites*. This specimen of *Triticites* cannot be identified specifically but enough remains to indicate that it is probably not older than Missouri. The maximum known range of *Triticites* is from the base of the Missouri through the Virgil into the base of the Wolfcamp. The other fossils listed are not yet finely classifiable even when well preserved, and have no close age significance.

Fusulinids were collected from the Horquilla Peak section of the Horquilla but no report has been made on these and they are presumably lost. Other fusulinid collections probably from the Horquilla that were reported on are from beds whose places in the section are not surely determined.

[6] The term "Lampasas" has not been officially adopted by the United States Geological Survey.

Of the Horquilla corals, Duncan (memorandum, July 22, 1947) states:

Characteristic cup corals from rocks definitely of Lampasas and Des Moines age in the area are the caninoids * * *, a few lophophyllids, * * * and specimens of zaphrentoid corals. Syringoporoid corals (*Multithecopora?* and *Syringopora*) occur both with collections of this age and with collections that may be younger. Bryozoans include incrusting fistuliporoids, Fenestellas, Rhomboporellas, stenoporoids, and other forms; *Prismopora* occurs in four collections all of which are of Lampasas and Des Moines age.

Pelecypods and gastropods are rare and indeterminate. About the trilobites tentatively identified in collection 9190, Weller (letter, March 3, 1947) says, "These look like Chester forms * * * might be *Kaskia chesterensis* but I am not certain."

It appears from the foregoing evidence that the top of the Horquilla in the Gunnison Hills section may be younger than the top of the Horquilla in the Horquilla Peak section. The paleontological evidence for the presence of post-Des Moines Pennsylvanian rocks above the zone of collection 9195 of the section in the Gunnison Hills area is, when all available evidence is considered, rather strong. Yet, though the beds above the zone of collection 8487 in the Horquilla Peak section may be late Pennsylvanian, the first evidence of fossils of late Pennsylvanian age in that section is in collection 8484, and it is not compelling evidence. This collection is from a zone near the top of the Horquilla in this section.

The fauna that characterizes the lower and perhaps middle part of the Horquilla has been listed in part by Girty (see "Selected bibliography"), in part by Stoyanow (1926, p. 311–320; 1936, p. 514–523), and in part by others. It is found in the middle and lower parts of the Galiuro limestone of Stoyanow in addition to being found in the Naco, of which the beds here called Horquilla were long considered to be a part. It is also present in part of the Magdalena limestone of New Mexico, and is widespread in the Rocky Mountain region in the lower Oquirrh, the Wells, Hermosa, and other formations.

The presence of a form identified by Stoyanow as *Orthotichia morganiana* (Derby) suggests to him that beds of post-Des Moines Pennsylvanian or younger age are present in the upper part of the Galiuro, as indeed thay are considered here to be in the upper part of the Horquilla and, of course, at some localities in some of the other formations mentioned above.

EARP FORMATION

The collections from the Earp formation are neither numerous nor large, and many of them have little or no age value. Those from the lower part of the formation are especially lacking in age significance. Brachiopods are still a dominant group; but in keeping with the general paucity of fossils, they are relatively few in number. Fusulinids occur in certain collections. Some few corals, bryozoans, and trilobites are known. Well-preserved gastropods are few, but cross sections are common on the surfaces of many beds. Echinoid spines are also common, especially in some of the black beds.

COLLECTIONS FROM EARP HILL

Collections from or near stratigraphic section of the Earp formation on south side of Earp Hill (see p. 19).

Collection 8967 (from unit 18 of stratigraphic section on p. 19 from upper 140 feet of formation).
- Crinoid stem
- *Spirifer?* sp. indet.
- *Neospirifer dunbari* King
- *Chonetes* sp. indet.
- *Pustula?* sp. undet.

Collection 8970 (from unit 22 of stratigraphic section on p. 19, about 15 or 20 feet stratigraphically below coll. 8967).
- Echinoid spines
- *Neospirifer dunbari* King
- *Composita* sp. indet.

Collection 8969 (from unit 30 of stratigraphic section on p. 20, about 85 feet stratigraphically below coll. 8970).
- *Linoproductus prattenianus* (Norwood and Pratten)

Collection 8968 (from same locality and stratigraphic zone as coll. 8969).
- "*Productus*"? sp. indet.

Collection ☆8938 (from zone in a section nearby thought to be about equal to a zone stratigraphically between the zones of colls. 8969 and 8508).
- *Triticites secalicus* (Say)
- sp. (probably)
- *Caninia* sp. A.?
- *Pseudoromingeria*? sp. B

Collection ☆8517 (from zone in a section nearby thought to be equal to a zone stratigraphically between the zones of colls. 8938 and 8508).
- *Caninia*? sp. A?
- *Lophophyllidium*? sp. D
- *Spirifer* sp. undet.
- *Crurithyris*? *expansa* (Dunbar and Condra)
- *Composita* sp. indet.

Collection 8508 (from unit 34 of stratigraphic section on p. 20).
- *Meekopora* sp. undet.
- *Rhombopora* sp. undet.
- *Neospirifer* sp. undet.
- *Phricodothyris perplexa* (McChesney)
- *Linoproductus prattenianus* (Norwood and Pratten)

Collection 8509 (from unit 37 of stratigraphic section on p. 20). No identifiable fossils

Collection ☆8937 (from zone in a section nearby thought to be in same stratigraphic position as zone of coll. 8509).
- *Caninia* sp. A
- Lophophyllid coral
- *Cleiothyridina orbicularis* (McChesney)
- *Composita subtilita* (Hall)
- *Dictyoclostus hermosanus* (Girty)?
- *Punctospirifer kentuckyensis* (Shumard)
- *Hustedia mormoni* (Marcou)

Collection ☆8518 (from zone in a nearby section thought to be at about same stratigraphic position as zone of colls. 8509 and ☆8937).
- *Caninia*? sp.
- *Multithecopora*? sp. A
- *Spirifer* sp. indet.
- *Neospirifer dunbari* King
  - sp. undet.
- *Phricodothyris perplexa* (McChesney)
- *Cleiothyridina orbicularis* (McChesney)
- *Composita subtilita* (Hall)
- *Dictyoclostus*? sp undet.
- "*Productus*"? sp. undet.
- *Punctospirifer kentuckyensis* (Shumard)
- *Hustedia mormoni* (Marcou)?
- *Dielasma bovidens* (Morton)

Collection ☆8936 (from a zone in an area nearby thought to be below zone of coll. 8509 and not more than 30 feet above base of formation).
- Crinoid stems
- *Fenestella* sp. undet.
- *Penniretepora* sp. indet.
- *Rhomboporella* cf. *R.* n. sp. A
- *Dictyoclostus*? sp. undet.
- *Linoproductus prattenianus* (Norwood and Pratten)
- "*Productus*," n. sp. A

Collection ☆8519 (from a zone in an area nearby thought to be in about same stratigraphic zone as coll. ☆8936).
- Lophophyllid? coral, sp. B?
- Crinoid stems
- Fistuliporid bryozoan, incrusting type 2
- *Tabulipora* sp. undet.
- *Polypora* sp. undet.
- *Ascopora* sp. undet.
- *Rhomboporella*, n. sp. A
  - n. sp. B
- *Neospirifer dunbari* King
- *Pustula*? sp. undet.
- *Linoproductus prattenianus* (Norwood and Pratten)
- "*Productus*," n. sp. A
- Pelecypods, indet. fragments

Probably no beds in this stratigraphic section are younger than early Virgil, if so young as that.

COLLECTIONS FROM THE GUNNISON HILLS

Collections from or near stratigraphic section of the Earp formation measured on east side of Gunnison Hills, 1 mile north of main peak in section 33, T. 15 S., R. 23 E. (see p. 21 to 22).

Collection ☆ 9402L (from a zone in an area nearby thought to be the equivalent of a zone about 125 feet below top of section in Gunnison Hills, given on p. 21, and about 112 feet above zone of coll. 9404D).
- Pelecypod? indet.
- *Omphalotrochus*? sp. indet.

Collection 9404D (from unit 28 of stratigraphic section on p. 21, about 137 feet stratigraphically below top of section).
- *Echinocrinus* sp. indet.

Collection 9404C (from unit 29 of stratigraphic section on p. 21).
- *Metacoceras* sp.
- *Mooreoceras* sp.
- *Perrinites* sp. (or might be *Properrinites*)
- Trilobite, gen. indet.

Collection ☆ 9405 (from a zone in a nearby area thought to be between zones of coll. 9404C and 9404B).
- *Fenestella* sp. undet.
- *Septopora* sp. undet.

Collection 9404B (from unit 38 of stratigraphic section on p. 22).
- Fistuliporoid bryozoan, gen. indet.
- *Stenodiscus*, n. sp. A
- *Polypora*? sp. indet.
- *Septopora* sp. undet.
- *Rhombopora*? sp. indet.
- *Composita*? sp. undet.
- "*Productus*" s. l., sp. undet.

Collection 9404A (from unit 49 of stratigraphic section on p. 22).
- *Schwagerina* cf. *S. longissimoidea* (Beede), sp. undet.
- *Ozawainella* sp.

Collection 9404 (from unit 54 of stratigraphic section on p. 22).
- *Stereostylus* sp. B
- *Echinocrinus* sp.
- Trepostomatous? bryozoan, gen. indet.
- *Neospirifer kansasensis* (Swallow)
- *Chonetes granulifer* Owen
- *Amphiscapha* sp. undet.

Collection 9403D (from unit 60 of stratigraphic section on p. 22).
- *Triticites* aff. *T. tumidus* Skinner
  - *obesus* (Beede)?
  - *ventricosus* (Meek and Hayden), n. var.?
- *Echinocrinus* sp.
- *Neospirifer kansasensis* (Swallow)?

Collection ☆ 9402K (from a zone in an area nearby thought to be stratigraphically between zones of coll. 9403D and 9403C).
- *Echinocrinus* sp.
- *Neospirifer kansasensis* (Swallow)
- *Chonetes granulifer* Owen

Collection ☆ 9402J (from a zone in an area nearby thought to be stratigraphically equivalent to zone of coll. 9403C).
- *Triticites* aff. *T. tumidus* Skinner
  - aff. *T. rothi* Skinner
- *Fistulotrypa* n. sp.

Collection 9403C (from unit 63 of stratigraphic section on p. 22).
- *Triticites* sp. undet.

Collection ☆ 9402I (from a zone in an area nearby thought to be stratigraphically between zones of coll. 9403C and 9403B).
- *Schwagerina* aff. *S. longissimoidea* (Beede)
- *Neospirifer kansasensis* (Swallow)?

Collection ☆ 9402H (from a zone in an area nearby essentially the same as zone of coll. 9402I).
- *Triticites* sp.
- Stenoporoid? bryozoan, gen. indet.
- Rhomboporoid bryozoan, gen. indet.

Collection 9403B (from unit 69 of stratigraphic section on p. 22).
- *Neospirifer kansasensis* (Swallow)?
- *Composita subtilita* (Hall)

Collection 9403A (from unit 75 of stratigraphic section on p. 22).
- *Triticites collumensis* Dunbar and Condra
  - *secalicus* (Say)?
- *Dunbarinella*? sp.

Collection ☆9402G (from a zone in an area nearby thought to be below that of coll. 9403A and about 100 feet above the base of the Earp formation).
- *Triticites ventricosus* (Meek and Hayden), n. var.?

COLLECTIONS FROM OTHER LOCALITIES

Two collections from the Earp formation that are not directly associated with any of the three stratigraphic sections given are the following:

Collection ☆8528.
- *Neospirifer kansasensis* (Swallow), n. var. A.
- *Phricodothyris perplexa* (McChesney) *perplexa* (McChesney), n. var. A.
- *Composita subtilita* (Hall)
- *Derbyia* cf. *D. crassa* (Meek and Hayden)
- *Chonetes granulifer* Owen
- *Pustula*? sp. undet.
- *Linoproductus prattenianus* (Norwood and Pratten)
- Pelecypods, 3 sp. undet.
- *Glabrocingulum*? sp. undet.
- *Amphiscapha* sp. undet.
- *Ditomopyge* sp. undet.

Collection ☆8529.
- *Echinocrinus* sp.
- *Septopora* sp. undet.
- *Composita* sp. undet.
- *Derbyia ciscoensis* Dunbar and Condra
- *Strophalosia* (*Heteralosia*?) sp. undet.
- *Amphiscapha* cf. *A. catilloides* (Conrad)

CHARACTER AND AGE OF THE FAUNA

Fusulinids are the most significant fossils in the collections from the Earp formation. Brachiopods, bryozoans, gastropods, and cephalopods give significant age guidance for certain collections.

The most significant brachiopod is *Neospirifer kansasensis* (Swallow) which characteristically occurs in rocks of late Pennsylvanian and early Permian(?) (Wolfcamp equivalent) age. *Neospirifer dunbari* King, though perhaps more characteristic of older rocks in general, overlaps the lower range of *N. kansasensis*. *Derbyia ciscoensis* Dunbar and Condra, present in collection 8529, also suggests later Pennsylvanian age. The absence of brachiopods generally characteristic of the lower half of the Pennsylvanian such as species and varieties of *Mesolobus* and Spirifers of the *rockymontanus* and *occidentalis* groups is to be expected but is nevertheless noteworthy.

Of the fusulinids studied in the following collections from the Gunnison Hills section of the Earp, Henbest (memorandum, June 24, 1947) says:

Collection 9404A (F6196): This sample contains *Schwagerina* of a general form of *S. longissimoidea* (Beede) and perhaps another more ventricose species; also a species of *Ozawainella*. These specimens of *Schwagerina* indicate Wolfcamp age, apparently not earlier than the topmost horizon of *Triticites* in the base of the Wolfcamp. The significance of the species of *Ozawainella* is not yet known or at least has not been described. I have observed a somewhat familiar form in the supposed Dothan limestone, Wolfcamp, of central Texas.

Collection 9403D (F6195): This sample contains *Triticites* aff. *T. tumidus* Skinner, *T. obesus* (Beede)?, and *Triticites ventricosus* (Meek and Hayden), n. var.? These indicate basal Wolfcamp or possibly but not likely uppermost Virgil age.

Collection 9402J (F6191): This sample contains two species of *Triticites* that occur at or very near the top of the range of this genus. These are closely related to *T. tumidus* Skinner 1931 and *T. rothi* Skinner 1931, which characterize the Foraker limestone of northern Oklahoma. Consequently, the age indication here is Wolfcamp [Permian?] and not Pennsylvanian as indicated on the label. Without more study and fuller succession of fusulinid fossils, I do not want to suggest anything closer than a rough correlation with the Foraker limestone, but the evidence for Wolfcamp age seems definite.

Collection 9403C (F6194): This sample contains a species of *Triticites* of rather uncertain relations. Its evolutionary position indicates approximately middle Virgil age, but it might be found to belong higher in the Virgil.

Collection 9402I (E6190): This sample contains *Schwagerina* aff. *S. longissimoidea* (Beede) which indicates age equivalent to the Wolfcamp or Big Blue series [of Permian (?) age]. This species seems to be a rather early form of *Schwagerina*. If this and the *Triticites* species of 9402H (F6189) are associated, the combined evidence would indicate basal Wolfcamp age.

Collection 9402H (F6189): This sample contains a species of *Triticites* that is characteristic of the uppermost Virgil or basal Big Blue series.

Collection 9403A (F6193): This sample contains *Triticites cullumensis* Dunbar and Condra 1927, *T. secalicus*? (Say), and possibly a species of *Dunbarinella*. The age indicated is middle or lower Virgil.

Collection 9402G (F6188): This sample contains numerous specimens of a variety of *Triticites ventricosus* (Meek and Hayden). In the Kansas section this form is found near the middle of the Virgil. I doubt that it is so old as lower Virgil or so young as the basal Big Blue, into which varieties of *T. ventricosus* range.

Fusulinids were examined in but one of the collections (8938) here listed from the Earp Hill section of the Earp. Henbest says of these fusulinids (memorandum, June 23, 1947):

> This contains a species of *Triticites* close to if not actually *T. secalicus* (Say) and perhaps another species of *Triticites*. These are definitely of upper Pennsylvanian age (unlikely as young as basal Permian) and more exactly appear to belong in or near the lower Virgil.

Regarding the Bryozoa, Duncan says (memorandum, July 22, 1947):

> *Septopora* was identified in one collection definitely assigned to the Earp. The genus seems to be characteristic of the upper Pennsylvanian and Permian? in this area, because specimens were not found in the collections from lower Pennsylvanian rocks (though the genus ranges from Mississippian to Permian). Another collection (8508) assigned to the Earp because of stratigraphic position contains *Rhombopora* and *Meekopora*. *Meekopora* occurs also with two species of undiagnostic brachiopods in collection 8485, which is tentatively assigned to the Earp. This genus is long ranging (Silurian to Permian), but no examples were found in our collections from the Horquilla and it is said that in the Pennsylvanian *Meekopora* is "common only in uppermost Virgilian beds" (see Moore, R. C., and others, 1944, p. 675). The Earp of the Gunnison Hills area contains bryozoans that have definite Permian affinities and that are much more distinctive than does the Earp of the type area. Among these are the genera *Fistulotrypa* and *Stenodiscus*. This may mean that there is a longer section of the Earp in the Gunnison Hills area.

Regarding the Earp gastropods, J. Brookes Knight says (memorandum, June, 1947):

Although *Amphiscapha* and *Glabrocingulum* are known to reach into beds of at least early Leonard age, they are both rare in the Permian. Both are exceedingly abundant in American Pennsylvanian; hence, the above suggest but do not prove Pennsylvanian age. Neither the genera nor the compared species (*Amphiscapha* cf. *A. catilloides*) are of value for placement in the Pennsylvanian so far as in now known. The Earp of course could be of Wolfcamp age too. The evidence of the gastropods is negative.

Cephalopods are confined to one collection (9404C) in the Earp and they are not specifically identifiable. The presence of a form identified by A. K. Miller as "*Perrinites* sp. (or might be *Properrinites*)" suggests Leonard or possibly Wolfcamp age for the upper part of the Earp in the Gunnison Hills area. Trilobites do not aid in age discrimination.

From a study of all the evidence presented by those who have studied various groups and from a first-hand examination of the brachiopods and from other evidence, it appears to the writer that the age of the Earp is from middle late Pennsylvanian to and including beds of Wolfcamp (Permian?) age, with the possibility that beds at the top of the formation in the Gunnison Hills may be younger than any beds in the Earp Hills and sections nearby. Certainly the evidence for the presence of beds of Wolfcamp age is stronger in the Gunnison Hills than in the Earp Hills area. Many of the collections in the latter area contain very little in the way of positive evidence for either late Pennsylvanian or Permian(?) age, but the assemblage seems to indicate that the Earp there is of either late Pennsylvanian or Permian(?) (Wolfcamp) age.

COLINA LIMESTONE

The most striking faunal characteristic of the Colina limestone is the large number of gastropods shown by cross sections where the rocks are broken and by an equally large number of echinoid spines. Identifiable gastropods are also common. Both of these types of fossils show up conspicuously on the surfaces of the black limestones that characterize the Colina because the remnants of the shelly material are often white. Brachiopods are relatively less common than in the Earp and much less common than in the Horquilla. Fusulinids are common in parts of the area. Corals and bryozoans are rarely seen.

Fossils are much more common in the upper part of the Colina than in the lower part.

COLLECTIONS FROM THE TOMBSTONE HILLS

Collections from or near stratigraphic section of Colina limestone measured on west slope of Colina Ridge in Tombstone Hills.

Collection 8965 (from unit 4 of stratigraphic section on p. 24, from a zone about 308 feet below top of formation).
- *Septopora* sp.
- *Dielasma?* sp.
- Pelecypods, 2 or 3 sp. undet.
- Gastropods, undet.

Collection 8964 (from unit 6 of stratigraphic section on p. 24).
- *Wellerella?* cf. *W. texana* (Shumard)
- *Composita* sp. indet.
- *Strophalosia?* sp. undet.
- *Dictyoclostus* cf. *D. ivesi* Newberry sp. undet.
- *Omphalotrochus* sp. indet.

Collection 8963 (from unit 7 of stratigraphic section on p. 24).
- Echinoid spines
- *Crurithyris?* sp. undet.
- Pelecypods, 2 or 3 sp. undet.
- *Bellerophon* sp. A
- *Worthenia* sp. indet.
- "*Murchisonia*" cf. *M. gouldii* Beede
- *Goniasma* sp. indet.
- *Euomphalus* sp. undet.
- *Omphalotrochus* sp. undet.
- *Naticopsis* sp. undet.
- *Orthonema?* sp. undet.

Collection 8962 (from unit 12 of stratigraphic section on p. 24 at base of formation.)
- *Strophalosia* (*Heteralosia?*) cf. *S. slocomi* (King)

COLLECTIONS FROM OTHER LOCALITIES

Collection 9405A was made from a stratigraphic section of the lower part of the Colina limestone in Gunnison Hills (see p. 25) and collection ☆9404E came from an area nearby. The first collection contains only a single form which was identified as an *Omphalotrochus* sp. undet. and the second contains only gastropod cross sections that are not even generically determinable.

Collection 9406 came from zone 6 of a stratigraphic section of the Colina limestone measured on the west slope of Scherrer Ridge NE¼ sec. 29, T. 15 S., R. 23, E., (see p. 25). It is from the middle part of the Colina and contains the following fossils:
- *Echinocrinus* sp.
- *Meekella?* cf. *M. pyramidalis* (Newberry)
- "*Productus*" s. l., sp. undet.
- *Retispira* sp. indet.
- Pleurotomarian gastropod, n. gen., n. sp.
- *Euomphalus* sp. undet.
- *Orthonema?* sp.

Collection ☆8488 (from zone about 30 feet above base of Colina, see locality register on p. 44).
- *Echinocrinus*
- *Wellerella?* cf. *W. texana* (Shumard)
- *Composita mexicana* (Hall)?
- Pelecypod, 1 sp. undet.
- *Yunnania*, n. sp.
- *Euomphalus*, n. sp. A
- *Omphalotrochus*, n. sp. A
- *Naticopsis*, sp. undet.
- *Orthonema?* sp. undet.
- Gastropod, n. gen.

Collection ☆8490 (from zone in upper part of Colina, see p. 44 for locality data).
- *Echinocrinus cratis* (White)?
  - *trudifer* (White)
  - sp.
- *Wellerella?* cf. *W. texana* (Shumard)
- *Derbyia multistriata?* (Meek and Hayden)?

Strophalosia? sp. undet.
Dictyoclostus occidentalis (Newberry) n. var. A
"*Productus*"? sp. undet.
Pelecypods, 3 sp. undet.
Goniasma? sp. undet.
Naticopsis sp. undet.
Dictomopyge? sp. undet.

Collection ☆8501 (from zone near middle of Colina. See p. 44 for locality data).
Echinocrinus
Fenestella? sp. undet.
Proretepora? sp. undet.
Septopora? sp. undet.
Composita mexicana (Hall)
Pelecypod, 1 sp. undet.
Bellerophon sp. undet.
Euphemites, sp. undet.
Warthia sp. undet.
Omphalotrochus obtusispira (Shumard)
Naticopsis sp. undet.
Gastropod, n. gen. X, n. sp.

Collection ☆8502 (from zone in Colina about 100 feet stratigraphically above that of coll. ☆8501 and at same locality).
Lophophyllidium? sp. A
Echinocrinus sp.
Fenestella? sp. undet.
Composita mexicana (Hall)
Goniasma? n. sp.
Omphalotrochus obtusispira (Shumard)
Orthonema? sp. undet.
Gastropod, n. gen. X, n. sp.
Meekospira? n. sp.

Collection ☆8503 (from zone in Colina about 75 feet stratigraphically above that of coll. ☆8502 at a nearby locality, see p. 44 for locality data).
Echinocrinus sp.
Wellerella? cf. *W. texana* (Shumard)
Dictyoclostus sp. undet.
Pelecypods, 4 sp. undet.
Plagioglypta? sp. undet.
Goniasma? sp.
Omphalotrochus, n. sp. A. (very large)
Anomphalus, n. sp.
Naticopsis sp. undet.
Orthonema? sp. undet.
Meekospira sp. undet.
Gastropod, n. gen. A., n. sp.
n. gen. B, n. sp. A
n. gen. C, n. sp.

Collection ☆8505 (from a zone in upper part of Colina, see p. 44 for locality data.)
Goniasma? sp. indet.
Perrinites sp. undet.

Collection ☆8510 (from Colina, horizon undetermined, see p. 44 for locality data.)
Yunnania sp. A
Euomphalus sp. indet.

Collection ☆8513 (from upper part of Colina, see p. 44 for locality data).
Echinocrinus
Composita mexicana (Hall)
Dictyoclostus occidentalis (Newberry), n. var. A
Pelecypod, 1 sp. undet.
Omphalotrochus obtusispira (Shumard)
n. sp. A

Collection ☆8516 (from upper part of Colina, see p. 44 for locality data).
Zaphrentoid coral, indet.
Composita mexicana (Hall)
Meekella cf. *M. pyramidalis* (Newberry)
? sp. indet.
Dielasma? sp.
Pelecypod, 1 sp. undet.
Gastropod, undet.

Collection ☆8973 (from a zone 50 feet below top of Colina, see p. 44 for locality data.)
Meekella cf. *M. pyramidalis* (Newberry)?
Strophalosia? sp. undet.
Dictyoclostus sp. undet.
Linoproductus (*Cancrinella*?) cf. *L. villersi* (D'Orbigny)

Collection ☆8975 (Colina?, see p. 44 for locality data.)?
Microdoma, n. sp.
Gastropod, n. gen. Y, n. sp.
Metacoceras? sp. undet.

Collection ☆8522 (from a zone in upper Colina; for locality data, see register of localities on p. 44).
Echinocrinus sp.
Fistulipora (ramose form)
Stenoporoid bryozoan (*Tabulipora*?)
Composita mexicana (Hall)
Chonetes sp. indet.
Dictyoclostus cf. *D. ivesi* (Newberry)
cf. *D. occidentalis* (Newberry)
Buxtonia? sp. undet.
Pelecypods, 3 sp. undet.
Gastropod, n. gen. Z, n. sp.
Euomphalus, n. sp. B

Collection ☆8976 (Colina, see p. 44 for locality data).
Echinoid spines and plates
Pelecypods, nuculoid, 1 sp. undet.
Microdoma, n. sp.
Strobeus sp. indet.
Gastropod, n. gen. A, n. sp. B
Gastropod, n. gen. C, n. sp. B

CHARACTER AND AGE OF THE FAUNA

The gastropods provide the largest faunal element in our collections from the Colina formation. They were studied by J. Brookes Knight, who reports on them as follows (memorandum, June 16, 1948):

The outstanding genus of the Colina collections is *Omphalotrochus*. (I am restricting this genus and, as restricted, I have not met with it above the Hess of the Glass Mountains, which is early Leonard in age.) The restricted genus is highly characteristic of beds of Wolfcamp age occurring abundantly in the central Texas Permian as high as Lueders, in the type Wolfcamp of the Glass Mountains, in the Hueco limestone of the Sierra Diablo, the Hueco and Sacramento Mountains, and of equivalent beds in southeastern California. Indeed, its range appears to coincide throughout the world with that of *Pseudoschwagerina*.

The species of *Omphalotrochus* (as restricted) appear to be highly variable—or else there is in the Wolfcamp beds of our Southwest a species complex that I have not yet been able to resolve. Omitting the genotype *O. whitneyi* of the McCloud formation of northern California, there is only one described species, *O. obtusispira* (Shumard). The Colina forms appear to be *O. obtusispira* or "varieties" of that species, and these and other "varieties" occur throughout the Wolfcamp beds of the Southwest.

They are quite distinct from the only species I know from post-Wolfcamp beds. Hence *Omphalotrochus obtusispira*, typical and varietal, is a very important factor in my belief that the Colina is of Wolfcamp age.

In addition to the evidence of *Omphalotrochus obtusispira* there are other gastropods that strengthen the Wolfcamp assignment of the Colina. For example *Yunnania* sp. A. is very close to a species abundant in the middle Hueco and the Talpa. I know no similar species in Leonard beds. Again "new genus B, n. sp. A" is identical with an undescribed Talpa form; "new genus A, n. sp. A" seems to be the same as a form abundant in the middle Hueco but is too poorly preserved for positive identification. "New genus C, n. sp. A" likewise occurs in the middle Hueco. The same may be said for the species tentatively identified as *Taosia crenulata* (Girty). *Euomphalus*, n. sp. A is abundant throughout the Wolfcamp beds of the Southwest Although it occurs in younger beds it seems relatively rare. It seems abundant in the Colina. Supporting the Wolfcamp assignment are the genera *Meekospira, Anomphalus*, and *Microdoma* which are characteristically Pennsylvanian. Although the first two are abundant in Wolfcamp beds, none of them have been met with above.

On the other hand, there are several elements which, if taken alone, suggest a younger age. The *Murchisonia* cf. *M. gouldii* Beede has been regarded hitherto as a Capitan species. Likewise *Euomphalus* sp. B seems to be a species I have met before only in the high Leonard and lower Word of the Glass Mountains. The *Goniasma* reported is too poor for identification but resembles more closely a Leonard representative of the genus than known Wolfcamp ones. However, these occurrences are overwhelmed by the mass of evidence pointing to Wolfcamp age.

[Knight further states in the same memorandum] In making this report [on the gastropods of the Colina and Epitaph] I am focusing on the gastropods alone. I know nothing of any other elements of the fauna or of the stratigraphic sequence. However, I repeat that the evidence from the gastropods suggests the assignment of the Colina and Epitaph to the Wolfcamp.* * * About a year ago [when] I reported to you on the gastropods of the area near Tombstone* * * I felt inclined to regard both the gastropods of the Colina and Epitaph as lower Leonard with the reservation that both could be Wolfcamp without serious jarring loose of fossils from previously known range. As you know, very little has been published on Permian gastropods and I was comparing the Tombstone gastropods with the large collections of Permian gastropods now being assembled at the U. S. National Museum on which, however, only preliminary work has been done.* * * I was particularly impressed by the similarity of the gastropods of the Colina and Epitaph with those of the marine Permian of central Texas, particularly with those of the Clyde and Lueders. I had not then proceeded far with my studies of the central Texas Permian snails and was then accepting the dictum * * * based on supposed tracing of an unconformity * * * that the Belle Plains, Clyde, and Lueders of that region were of Leonard age.

A month or so later, however, I had progressed to the point where I had been compelled by the close similarity and general identity of the gastropods of north-central Texas with those of the Hueco limestone of Wolfcamp age and almost complete lack of Leonard forms to recognize that the north-central Texas Permian up to and including the Lueders is also of Wolfcamp age. This conclusion was subsequently supported by Miller and Youngquist, 1947, and by Miller and Purizek, 1948, working with the ammonoids. As a result of this readjustment in the determined age of the faunas used as standards of comparison, I was forced also to readjust my conclusions on the Colina and Epitaph of the Tombstone area.* * * I have reviewed the gastropod collections of the Colina and Epitaph in the light of my continued studies on the Permian gastropods of north-central Texas, the Glass Mountains, the Hueco and Sacramento Mountains. As a result I feel even more strongly that those parts of the Colina from which the gastropods came and the Epitaph are to be correlated with the middle (and perhaps upper) Hueco limestone and with the Belle Plains, Clyde, and Lueders of central Texas. As stated above, all of these seem to be of Wolfcamp age. I have too little evidence to say whether or not the lower part of the Hueco limestone and of the central Texas Wolfcamp beds have equivalents in the Tombstone area. Likewise, so far I lack gastropods from the highest Hueco for comparison. The gastropod faunas of none of the beds I have discussed above show affinities to those of the Leonard of the Glass Mountains or of the Bone Springs of the Sierra Diablo region of west Texas.

Fusulinids are present in the Colina and doubtless could contribute much in the way of stratigraphic evidence. The unfortunate loss of our collections of these invertebrates prevents a discussion of their age significance.

But one of the cephalopods collected has age significance. This cephalopod comes from a zone thought to be in the upper part of the Colina. It was identified by A. K. Miller (personal communication, February 6, 1947) who says regarding it: "Collection 8505 contains one silicified specimen that is almost certainly referable to *Perrinites* and therefore is most probably Leonard in age." The fact that this is silicified and seems to be but tentatively identified detracts from its stratigraphic value.

The corals and bryozoa collected from the Colina are not distinctive.

The brachiopod fauna of the Colina, as represented in our collections, is not large. Species that have been identified in several collections are a *Wellerella* cf. *W. texanus* Shumard, *Composita mexicana* Hall, a *Meekella* cf. *M. pyramidalis* (Newberry), a new variety of *Dictyoclostus occidentalis* (Newberry), a *Linoproductus* (*Cancrinella*) cf. *L. villersi* (D'Orbigny), and a *Strophalosia* (*Heteralosia*) cf. *slocomi* (King). Other forms that occur are a *Dictyoclostus* cf. *D. ivesi* (Newberry) and a *Derbyia multistriata* (Meek and Hayden.) The two species of *Dictyoclostus*, the *Derbyia multistriata* and the *Linoproductus*, have been recognized in the collections only from beds that so far as known occur in the upper half of the Colina. The *Wellerella* and the *Composita* range from near the base to the top.

All of the brachiopods mentioned above, except the *Strophalcsia*, suggest beds that are of Wolfcamp or younger age. Many of them suggest post-Wolfcamp more than Wolfcamp.

The fact that the brachiopods that suggest post-Wolfcamp most strongly are found in these collections only from beds in the upper Colina—*M. pyramidalis*, *Dictyoclostus ivesi*, *D. occidentalis*, and *Derbyia multistriata*—suggests to the writer that possibly the same situation as is said to exist in the Hueco limestone exists here. In the Hueco limestone the upper part is said to be probably Leonard and the lower part Wolfcamp (King, 1942, p. 556–560). The fact that so many of these species are represented by varieties or by tentatively identified specimens decreases their age significance and the uncertainties now existing regarding the limits and contents of the various units in west Texas makes a definite age decision very difficult. The brachiopods bear a stronger resemblance to the Kaibab (s. l.) than to brachiopod faunas of the west Texas regions.

Because of Knight's views on the gastropods and because the brachiopods and one cephalopod seem to suggest that the middle and upper part is Leonard or younger, the writer will here consider the Colina to be Wolfcamp and Leonard(?) in age.

EPITAPH DOLOMITE

Fossils are rarely seen in the Epitaph dolomite and a few collections are all that exist. This dearth of fossils is due in part to a relatively small area of surface exposure and in part to the small proportion of beds that are fossiliferous. Fossils are especially rare in the dolomite beds or zones of the formations; likewise in the red shales and in the conglomerate beds, where paleoecological conditions probably prevented the existence of profuse life assemblages.

COLLECTIONS FROM THE TOMBSTONE HILLS

Collections from a stratigraphic section of Epitaph dolomite measured on dip slope of Colina Ridge, west of Epitaph Gulch, 1 mile south of Horquilla Peak (see p. 26).

Collection 8515 (from unit 1 of stratigraphic section on p. 26 from a zone in a blue limestone 103 feet thick at top of formation).
- *Neospirifer* sp. undet.
- *Composita mexicana* (Hall)
- *Dictyoclostus?* sp. undet.
- "*Productus*" sp. undet.

Collection 8966 (from unit 18 of stratigraphic section on p. 27).
- *Composita mexicana* (Hall)?
- *Dictyoclostus* cf. *D. occidentalis* (Newberry)
- Gastropod n. gen. Z, n. sp.

COLLECTIONS FROM OTHER LOCALITIES

Collections from Epitaph formation but not from measured sections given in this report. (For locality data, see register of localities on p. 44).

Collection ☆8521 (from zone in upper part of Epitaph).
- *Plerophyllum?* sp.
- *Composita mexicana* (Hall)
- *Goniasma* sp. undet.

Collection ☆8526.
- *Echinocrinus* sp.
- *Composita mexicana* (Hall)?
- *Yunnania?* sp. B
- *Worthenia*, n. sp. A
- *Goniasma* sp. undet.
- *Euomphalus* sp. undet.

Collection ☆8527.
- *Composita* sp. undet.
- *Yunnania* sp. B
- *Worthenia* sp. undet.
- *Goniasma* sp. undet.
- *Euomphalus* sp. undet.
- *Omphalotrochus obtusispira* (Shumard)

CHARACTER AND AGE OF THE FAUNA

The fauna of the Epitaph, as represented in the collections, contains, insofar as they are identifiable, few forms not present in the Colina. Though not so varied, the brachiopod fauna contains two forms present in the Colina, *Dictyoclostus* cf. *D. occidentalis* and *Composita mexicana*. The *Dictyoclostus* occurs in the upper part of the Colina in the fauna that the writer believes is probably the equivalent of the Kaibab (possibly the Toroweap division of McKee) and of the upper part of the Hueco. The other brachiopods in the collections are not definitely determinable as to species and some of them not as to genus.

Knight says (memorandum cited), regarding the gastropods of the Epitaph:

> Except that there are fewer collections of fewer species, there is no present basis for distinguishing between the gastropod faunas of the Epitaph and the Colina. *Worthenia* sp. A seems to be a new element but this has little significance. The *Omphalotrochus* and several other species are the same as those of the Colina.

A single fragment of a solitary rugose coral is listed in collection ☆8521, from the railroad cut in the NE¼ sec. 32, T. 19 S., R. 22 E. Regarding this coral, Duncan says, "It is tentatively identified as a *Plerophyllum*, a genus known from the Permian of Australia, Asia, and Russia, but hitherto not reported in North America."

Although the evidence is far from complete, it appears to the writer that the Epitaph fauna is but a slightly smaller representative of the fauna of the upper Colina. His tendency would be to refer it to the Leonard and to possible equivalency with the lower Kaibab (perhaps Toroweap of McKee). The presence in it of *Omphalotrochus obtusispira* would perhaps indicate, in the present state of knowledge, that there is evidence of a Wolfcamp age, but this evidence is, in the writer's present and tentative opinion, overbalanced by the supposed stratigraphical position of the Epitaph above the Colina and by the resemblance of the Epitaph brachiopods to forms from beds younger than Wolfcamp.

SCHERRER FORMATION

A striking feature of the Scherrer formation is the abundance of echinoid spines that are preserved on most of the surfaces of the limestone beds. No other fossils were collected from the formation, so that its age must be determined by its stratigraphic position above the Colina and below the Concha. Collection 9407 from unit 11 of stratigraphic section of the Scherrer formation (see p. 28) consists wholly of echinoid spines which have no stratigraphic significance.

CONCHA LIMESTONE

The collections from the Concha are not large, and therefore they may not adequately represent the total fauna of the formation. As represented by the collections, the Concha fauna has much in contrast to the faunas of the Colina, but it is probable that the age difference is very great. The fauna is mostly of brachiopods and bryozoans. Gastropods were probably not important for they are not present in any of our admittedly inadequate collections. Fusulinids, if present, were not found. Few corals were found. Echinoid spines are not common. Many brachiopods are preserved in silica and these have been dissolved from the matrix by hydrochloric acid.

Collections from Scherrer Ridge

Collections from stratigraphic sections of Concha limestone measured on east end of Concha ridge, Gunnison Hills, NW¼ sec 28, T. 15 S., 23 E. (See p. 29.)

Collection 9407C (from a zone about 25 to 60 feet below top of formation and in unit 1 of stratigraphic section on p. 29).
- *Meekella* cf. *M. grandis* King
- ?, n. sp. A

Collection 9407B (from a zone in unit 1 of stratigraphic section on p. 29 about 10 to 20 feet below that of coll. 9407C).
- *Striatopora?* sp. indet.
- Fistuliporoid bryozoan, gen. undet.
- *Stenodiscus* sp. A?
- *Clausotrypa?* sp. undet.
- *Dictyoclostus ivesi bassi* (McKee)
- *occidentalis* (Newberry)
- *Punctospirifer?* sp. undet.

Collection 9407A (from a zone in unit 1 of stratigraphic section on p. 29 about 10 to 20 feet below that of coll. 9407B).
- *Fistulipora?*, n. sp. A
- ?. n. sp. B
- Several fistuliporoid bryozoans, gen. undet.
- *Septopora* sp.
- *Clausotrypa*, n. sp.
- *Derbyia?* cf. *D. crenulata* Girty
- ? sp.
- *Meekella* cf. *M. grandis* King.
- *Chonetes?* sp.
- *Dictyoclostus ivesi bassi* (McKee)
- *occidentalis* (Newberry)
- *Buxtonia?* sp. undet.
- "*Productus*" s. l., sp. undet.
- *Reticulariina?* cf. *R. laxa* (Girty)
- *Acanthopecten?* sp. undet.

This fauna recalls the fauna reported by Stoyanow (1926, p. 318) from the region of Paradise, Ariz., in the Chiricahua Mountains. Two collections made by James Gilluly and James Steele Williams on July 1, 1938, from an area near Paradise are probably from the limestone that Stoyanow in 1936 called the Chiricahua limestone. These collections are given below.

COLLECTIONS FROM OTHER LOCALITIES

Collection ☆8989 (for locality data, see register of localities on p. 44).
- *Amplexocarina?* sp.
- Crinoid columnals
- *Echinocrinus*
- Fistuliporoid bryozoans, incrusting forms
- *Fenestella?* sp.
- *Bicorbis arizonica* (Condra and Elias)
- *Phricodothyris* sp.
- *Derbyia?* cf. *D. crenulata* Girty
- *Meekella?* cf. *M. grandis* King
- *Dictyoclostus ivesi bassi* McKee
- *Dictyoclostus occidentalis* (Newberry)
- Bellerophontid gastropod, gen. and sp. indet.

Collection ☆8990 (for locality data, see register of localities on p. 44).
- *Amplexocarina* sp.
- Crinoid stems
- Echinoid plate
- *Derbyia?* cf. *D. buchi* (D'Orbigny)
- ? cf. *D. crenulata* Girty
- *Meekella?* cf. *M. grandis* King
- *Dictyoclostus* cf. *D. invesi* Newberry
- *Dictyoclostus occidentalis* (Newberry)?

CHARACTER AND AGE OF THE FAUNA

A comparison of the faunal lists here presented show that the brachiopod faunas of the Concha and of the Chiricahua of Stoyanow near Paradise have several species in common.

The brachiopods species of the Concha, furthermore, include significant forms that are characteristically present in assemblages of the Kaibab (as restricted by McKee) and one such is the form here referred to as *Dictyoclostus ivesi bassi* (McKee). Another form commonly associated in Kaibab faunas with this species is *Dictyoclostus occidentalis* (Newberry) s. l. (including the form described as *D. meridionalis*); on the other hand, *Derbyia crenulata* Girty, and *Meekella grandis* King, present in both the Concha and the Chiricahua, are species originally described from west Texas.

Of the Concha bryozoans Duncan says (memorandum, July 22, 1947):

> In addition to *Septopora*, the Concha contains large ramose *Fistulipora?*, *Clausotrypa*, and *Stenodiscus*, all characteristic Permian types. [She says further] The distinctive bryozoan *Bicorbis*, a specimen of which was obtained at the locality of

collection ☆8989, occurs very widely in the Kaibab and, as yet, has not been recorded from any other formation.

The Concha limestone, on the basis of its brachiopod fauna, is probably the equivalent of the Chiricahua limestone of Stoyanow. The Chiricahua is correlated by Stoyanow (1936, p. 532) with member Beta of the Kaibab, as restricted by McKee, of the Grand Canyon region, a correlation that the writer believes is probably as nearly correct as can be made on evidence now available. The fauna of the Concha is not of sufficient size to support a positive correlation with the Kaibab, but such a correlation is indicated.

The age of the Kaibab (or of specific zones in it) and of the Toroweap of McKee relative to the units of the west Texas section are in dispute. The various interpretations and the data on which they are based have been discussed by McKee (1938, p. 153–176), Robert E. King (1930, p. 29–30), Philip B. King (1934) and others. Some of the reasons for the uncertainties have been discussed by the writer on page 30 of this report. The number of writers that have in one way or another discussed these ages is so large that it would be impossible to refer to all of them. In summary, it may be said that it appears that most of these writers consider the fauna best known as characteristic of the Kaibab (likely that of the Beta member of the Kaibab as restricted by McKee) to be probably of Leonard age. Several others, however, consider this fauna to of Word age. At present the writer is inclined toward a correlation with the Leonard, but it must be admitted that there are also elements that suggest correlation with the Word. It is difficult to judge which group of elements gives the stronger evidence, and certainly neither makes a clear-cut decision possible.

The age equivalent of the Snyder Hill formation of Stoyanow is probably the Concha but it may be in part the Colina. Stoyanow (1942, p. 1277) considers his Snyder Hill older than his Chiricahua limestone which is considered in this paper as the equivalent of McKee's Beta member of the Kaibab. At least one of Stoyanow's localities (1936, p. 530–531) is one of the localities of the Concha limestone of this report. This locality is described as the "limestone underlying the basal Comanche in the Little Dragoons." McKee and Hernon (letter from McKee, March 4, 1953) believe that Stoyanow's Snyder Hill is mainly equal to the Concha of this report, but in places beds of the Colina seem to have been included in it. Because this formation was not in the area mapped, it was not studied in detail by the authors of this report.

REGISTER OF U. S. GEOLOGICAL SURVEY COLLECTIONS FROM FORMATIONS OF THE NACO GROUP THAT ARE OUTSIDE THE STRATIGRAPHIC SECTIONS DESCRIBED IN THIS REPORT

HORQUILLA LIMESTONE

☆8480. Benson quadrangle, Arizona. Altitude about 4,750 ft, in creek bed of main tributary of Tombstone Canyon from south, about 1 mile from southeast corner of Benson quadrangle. From about the same place as coll. 8479. James Gilluly, 1937.

☆8482. Benson quadrangle, Arizona. Lower part of shaly series in west wall of south tributary of Tombstone Canyon about 1¼ miles west and 2000 ft north of southeast corner of Benson quadrangle. James Gilluly, 1937.

☆8483. Benson quadrangle, Arizona. From same locality as coll. ☆8482 and about 75 ft stratigraphically above it. James Gilluly, 1937.

☆8484. Benson quadrangle, Arizona. From divide extending west along south edge of Benson quadrangle, about 1⅝ miles west of southeast corner. Probably 100 ft stratigraphically above coll. ☆8483. James Gilluly, 1937.

☆8487. Benson quadrangle, Arizona. Low butte 2¾ miles west and 1¾ miles north of southeast corner of Benson quadrangle. Just above alluvium north of old Telegraph Road. James Gilluly, 1937.

☆9403. Dragoon quadrangle, Arizona. East spur of hill 5005 in NW¼ sec. 33, T. 15 S., R. 23 E. T. W. Amsden and F. W. Farwell, April 17, 1945.

☆9195. Dragoon quadrangle, Arizona. Northwestern part Little Dragoon Mountains, SE¼ sec. 10, T. 15 S., R. 22 E. T. W. Amsden, May 16, 1944.

☆9191. Dragoon quadrangle, Arizona. Northern part of Little Dragoon Mountains. East central part of sec. 9, T. 15 S., R. 22 E. T. W. Amsden, May 12, 1944.

☆9190. Dragoon quadrangle, Arizona. Northern part of Little Dragoon Mountains. East central part of sec. 9, T. 15 S., R. 22 E. T. W. Amsden, May 9, 1944.

☆9194. Dragoon quadrangle, Arizona. Northeastern part of Little Dragoon Mountains. NE¼ sec. 15, T. 15 S., R. 22 E. T. W. Amsden, May 15, 1944.

☆8946. Pearce quadrangle, Arizona. About 2 miles southeast of Gleeson. SE¼ sec. 5, T. 20 S., R. 25 E. James Gilluly and R. S. Cannon, Jr., 1938.

☆8948. Pearce quadrangle, Arizona. About 2 miles southeast of Gleeson. Thrust plate of limestone overlying Bolsa and Abrigo. NE¼ sec. 5, T. 20 S., R. 25 E. James Gilluly and R. S. Cannon, Jr., 1938.

EARP FORMATION

☆8517. Benson quadrangle, Arizona. Low ridge just west of common corner of secs. 26 and 34, T. 20 S., R. 22 E. James Gilluly, 1937.

☆8518. Benson quadrangle, Arizona. From same locality as coll. ☆8517. James Gilluly, 1937.

☆8519. Benson quadrangle, Arizona. From slightly west of locality of coll. ☆8518. James Gilluly, 1937.

☆8528. Pearce quadrangle, Arizona. In gulch, 2000 ft northeast of crest of hill 5501 in sec. 23, T. 21 S., R. 23 E. James Gilluly, 1937.

☆8529. Pearce quadrangle, Arizona. From 1500 ft northeast of crest of same hill as coll. ☆8528. James Gilluly, 1937.

☆8936. Benson quadrangle, Arizona. From about 4 miles southwest of Tombstone. From slightly west of locality of coll. ☆8938. James Gilluly and J. S. Williams, June 22, 1938.

☆8937. Benson quadrangle, Arizona. From place about 4 miles southwest of Tombstone. From same locality as coll. ☆8938. James Gilluly and J. S. Williams, June 22, 1938.

☆8938. Benson quadrangle, Arizona. From about 4 miles southwest of Tombstone. Low ridge just west of common corner of secs. 26 and 34, T. 20 S., R. 22 E. James Gilluly and J. S. Williams, June 22, 1938.

☆9402G. Dragoon quadrangle, Arizona. Northern part of sec. 4, T. 16 S., R. 23 E. (Gunnison Hills). T. W. Amsden and F. W. Farwell, April 14, 1945.

☆9402H. Dragoon quadrangle, Arizona. Northern part of sec. 4, T. 16 S., R. 23 E. (Gunnison Hills). T. W. Amsden and F. W. Farwell, April 14, 1945.

☆9402I. Dragoon quadrangle, Arizona. Northern part of sec. 4, T. 16 S., R 23 E. (Gunnison Hills). T. W. Amsden and F. W. Farwell, April 14, 1945.

☆9402J. Dragoon quadrangle, Arizona. Northern part of sec. 4, T. 16 S., R. 23 E. (Gunnison Hills). T. W. Amsden and F. W. Farwell, April 14, 1945.

☆9402K. Dragoon quadrangle, Arizona. Northern part of sec. 4, T. 16 S., R. 23 E. (Gunnison Hills). T. W. Amsden and F. W. Farwell, April 14, 1945.

☆9402L. Dragoon quadrangle, Arizona. Northern part of sec. 4, T. 16 S., R. 23 E. (Gunnison Hills). T. W. Amsden and F. W. Farwell, April 14, 1945.

☆9405. Dragoon quadrangle, Arizona. Small knob in northwest corner of SE¼ sec. 29, T. 15 S., R. 23 E. (Gunnison Hills). T. W. Amsden and F. W. Farwell, April 18, 1945.

COLINA LIMESTONE

☆8488. Pearce quadrangle, Arizona. From top of 5501 hill, in SW¼ sec. 23, T. 21 S., R. 23 E. James Gilluly, 1937.

☆8490. Benson quadrangle, Arizona. Altitude 4,650 ft, west slope of butte in NE¼ sec. 19, T. 21 S., R. 23 E. James Gilluly, 1937.

☆8501. Benson quadrangle, Arizona. 800 ft south-southwest of BM 5700, on steep cliff (T. 21 S., R. 23 E.). James Gilluly, 1937.

☆8502. Benson quadrangle, Arizona. From same locality as coll. ☆8501. About 100 ft stratigraphically above coll. ☆8501. James Gilluly, 1937.

☆8503. Benson quadrangle, Arizona. From about 15 ft stratigraphically below BM 5700, in T. 21 S., 23 E., on top of big butte. James Gilluly, 1937.

☆8505. Benson quadrangle, Arizona. NE¼ sec. 7, T. 21 S., R. 23 E. James Gilluly, 1937.

☆8510. Benson quadrangle, Arizona. Small outlying hill on line between Pearce and Benson quadrangles, 1 mile south of north line of T. 21 S. James Gilluly, 1937.

☆8513. Benson quadrangle, Arizona. Top of hill 5230, on line between Rs. 22 and 23 E., T. 20 S. James Gilluly, 1937.

☆8516. Benson quadrangle, Arizona. Low on dip slope of ridge in center of sec. 26, T. 20 S., R. 22 E. James Gilluly, 1937.

☆8522. Benson quadrangle, Arizona. North spur of the Three Brothers Peaks, just north of porphyry contact. James Gilluly, 1937.

☆8973. Benson quadrangle, Arizona. Head of Government Draw, SE¼ sec. 5, T. 21 S., R. 23 E. on hill which is about on boundary between secs. 4 and 5 and south across a saddle from hill outlined on topographic sheet by a numbered 5000-foot contour line: on crest of hill and slightly below (5–10 ft) on east side and slightly below on west side. James Gilluly and J. S. Williams, June 24, 1938.

☆8975. Pearce quadrangle, Arizona. About 2 miles southeast of Gleeson. Near center, sec. 4, T. 20 S., R. 25 E. James Gilluly and R. S. Cannon, Jr., 1938.

☆8976. Pearce quadrangle, Arizona. About 2 miles southeast of Gleeson. About 4,200 ft due north of southeast corner of sec. 5, T. 20 S., R. 25 E. James Gilluly and R. S. Cannon, Jr., 1938.

EPITAPH DOLOMITE

☆8521. Benson quadrangle, Arizona. Northeast of railroad track, NE¼ sec. 32, T. 19 S., R. 22 E. James Gilluly, 1937.

☆8526. Benson quadrangle, Arizona. Low slopes of hogback about 200 ft due north of common south corners of Rs. 22 and 23 E., T. 20 S. James Gilluly, 1937.

☆8527. Benson quadrangle, Arizona. Crest of ridge north of locality of coll. ☆8526. James Gillully, 1937.

SCHERRER FORMATION

(None.)

CONCHA LIMESTONE

☆8989. Chiricahua quadrangle, Arizona and New Mexico. NW¼NE¼ sec. 15, T. 17 S, R. 31 E., at mouth of canyon leading to Round Valley (BM 5252). On north side of canyon at mouth below first big cliff but within 100 ft of it. J. S. Williams and James Gilluly, July 1, 1938.

☆8990. Chiricahua quadrangle, Arizona and New Mexico. NW¼NE¼ sec. 15, T. 17 S., R. 31 E., at mouth of canyon leading to Round Valley (BM 5252). On north side of canyon northwest of locality of coll. ☆8989 on back of cliff which is 300 ft stratigraphically above top of cliff. J. S. Williams and James Gilluly, July 1, 1938.

SELECTED BIBLIOGRAPHY

[Because this report was essentially completed in 1947, this list does not include literature published since that date. An attempt has been made to include literature rich in bibliographic references to the region]

Brown, W. H., 1939, Tucson Mountains, an Arizona basin ran type: Geol. Soc. America Bull., v. 50, p. 697–760.

Butler, B. S., and Wilson, E. D., 1938, Some Arizona ore deposits: Arizona Bur. Mines Bull. 145, geol. ser. no. 12 (Tombstone district), p. 104–110.

Butler, B. S., Wilson, E. D., and Rasor, C. H., 1938, Geology and ore deposits of the Tombstone district, Arizona: Arizona Bur. Mines Bull. 143, geol. ser. 10, 114 p.

Darton, N. H., 1925, A résumé of Arizona geology: Arizona Bur. Mines Bull. 119, 298 p. [Contains fossil lists by Girty and others.]

——— 1926, The Permian of Arizona and New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 10, no. 9, p. 819–852. [Contains fossil lists by G. H. Girty.]

——— 1928, "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, 356 p.

Dunbar, Carl O., and Condra, G. E., 1932, Brachiopoda of the Pennsylvanian system in Nebraska: Nebraska Geol. Survey Bull. 5, 2d ser., 377 p.

Girty, G. H., 1903a, Fossil lists *in* Ransome, F. L., Geology of the Globe copper district, Arizona: U. S. Geol. Survey Prof. Paper 12, p. 42–44.

——— 1903b, The Carboniferous formations and faunas of Colorado: U. S. Geol. Survey Prof. Paper 16.

Girty, G. H., 1904, Fossil lists and illustrations *in* Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, p. 46–54.

——— 1905a, Fossil lists *in* Lee, W. T., Underground waters of Salt River Valley, Arizona: U. S. Geol. Survey Water-Supply Paper 136, p. 97–98.

——— 1905b, Fossil list *in* Lindgren, W. L., The copper deposits in the Clifton-Morenci district, Arizona: U. S. Geol. Survey Prof. Paper 43, p. 72.

——— 1908, The Guadalupian fauna: U. S. Geol. Survey Prof. Paper 58.

——— 1910, Fossil lists *in* Darton, N. H., A reconnaissance of parts of northwestern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, p. 24, 30, 36, 37.

——— 1915, Fossil lists *in* Schrader, F. C., Mineral deposits of Santa Rita and Patagonia Mountains, Arizona: U. S. Geol. Survey Bull. 582, p. 49–50.

——— 1916, Fossil lists *in* Ransome, F. L., Some Paleozoic sections in Arizona and their correlation: U. S. Geol. Survey Prof. Paper 98-K, p. 143, 147, 148–149, 152, 162.

——— 1919, Fossil lists *in* Ransome, F. L., The copper deposits of Ray and Miami, Arizona, U. S. Geol. Survey Prof. Paper 115, p. 47–48.

——— 1927, Fossil lists and descriptions *in* Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, p. 76, 78, 93–94, 411–446.

——— 1928, Fossil lists *in* Gilluly, James, and Reeside, J. B., Jr., Sedimentary rocks of the San Rafael Swell and some adjacent areas in southeastern Utah: U. S. Geol. Survey Prof. Paper 150–D, p. 64–66.

——— 1931, Fossil lists *in* Hewett, D. F., Geology and ore deposits of the Goodsprings quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 162, p. 19–21, 24–29, 31–32, 33.

——— 1932, Fossil lists *in* Gilluly, James, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U. S. Geol. Survey Prof. Paper 173, p. 23–24, 26, 28, 30–31, 33–34, 36–37.

——— 1935, Fossil lists *in* Nolan, T. B., The Gold Hill mining district, Utah: U. S. Geol. Survey Prof. Paper 177, p. 26, 28–29, 30–31, 32, 33.

——— 1942, Lists of fossils *in* Loughlin, G. F. and Koschman, A. H., Geology and ore deposits of Magdalena mining district, New Mexico: U. S. Geol. Survey Prof. Paper 200, p. 16, 21.

Gutschick, R. C., 1943, The Red Wall limestone (Mississippian) of Yavapai County, Arizona [abs.]: Plateau, v. 16, no. 6, p. 1–11.

Hernon, R. M., 1935, The Paradise formation and its fauna: Jour. Paleontology, v. 9, no. 8, p. 653–696.

King, P. B., 1934, Permian stratigraphy of trans-Pecos, Texas: Geol. Soc. America, v. 45, p. 697–798. [Has many references not separately listed in this report.]

King, P. B., 1942, Permian of west Texas and southeastern New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 26, no. 4, p. 535–760.

King, R. E., 1931, Geology of the Glass Mountains, Texas; Pt. 2, Faunal summary and correlation of the Permian formations, with descriptions of Brachiopoda: Texas Univ. Bull. 3042 245 p.

McKee, Edwin D., 1938, The environment and history of the Toroweap and Kaibab formations of northern Utah: Carnegie Inst. Washington Publ. 492.

——— 1947, Paleozoic seaways in western Arizona: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 282–292.

Moore, R. C. and others, 1944, Correlation of the Pennsylvanian formations of North America: Geol. Soc. America Bull., v. 55, p. 657–706.

Newell, N. D., 1948, Key Permian section, Confusion Range, western Utah: Geol. Soc. America Bull., v. 59, no. 10, p. 1054.

Noble, L. F., 1928, A section of the Kaibab limestone in Kaibab Gulch, Utah: U. S. Geol. Survey Prof. Paper 150–C, p. 41–60.

Nolan, T. B., 1935, The Gold Hill mining district, Utah: U. S. Geol. Survey Prof. Paper 177.

Ransome, F. L., 1904, The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21.

——— 1913, The Turquoise copper-mining district, Arizona: U. S. Geol. Survey Bull. 530, p. 125–134.

——— 1916, Some Paleozoic sections in Arizona and their correlation: U. S. Geol. Survey Prof. Paper 98, p. 133–166.

——— 1920, Geologic map of Tombstone district *in* Jones, E. L., Jr., and Ransome, F. L., Deposits of managanese ore in Arizona: U. S. Geol. Survey Bull. 710, p. 93–184.

Reagan, A. B., 1903, Geology of the Fort Apache region, Arizona: Am. Geologist, v. 32, no. 5, p. 265–308.

——— 1904, Some fossils from the lower Aubrey and Upper Red Wall limestones in the vicinity of Fort Apache, Ariz.: Indiana Acad. of Sci. Proc. for 1903, p. 237–246.

Reeside, J. B., Jr., and Bassler, Harvey, 1922, Stratigraphic sections in southwestern Utah and northeastern Arizona: U. S. Geol. Survey Prof. Paper 129, p. 53–77.

Robinson, H. H., 1913, The San Francisco volcanic field, Arizona: U. S. Geol. Survey Prof. Paper 76.

Shimer, H. W., 1919, Permo-Triassic of northwestern Arizona: Geol. Soc. America Bull., v. 30, p. 471–498.

Stoyanow, A. A., 1926, Notes on recent stratigraphic work in Arizona: Am. Jour. Sci., 5th ser., v. 12, p. 311–324.

——— 1936, A correlation of Arizona Paleozoic formations: Geol. Soc. America Bull., v. 47, no. 4, p. 459–540.

——— 1942, Paleozoic paleogeography of Arizona: Geol. Soc. America Bull., v. 53, p. 1255–1282.

Schrader, F. C., 1915, Mineral deposits of Santa Rita and Patagonia Mountains, Arizona: U. S. Geol. Survey Bull. 582.

Weller, Stuart, 1914, Mississippian brachiopods of the Mississippi valley basin: Illinois Geol. Survey Mon. 1.

Wilson, E. D., 1927, Geology and ore deposits of the Courtland-Gleeson region, Arizona: Arizona Bur. Mines Bull. 123.

INDEX

O