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Mississippian-Pennsylvanian Boundary
in Southern Nevada

by

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INTRODUCTION

Stratigraphic placement of the Mississippian-Pennsylvanian Boundary in the Great Basin has been either uncertain or subject to variation, except where an unconformity separates unquestioned Mississippian and Pennsylvanian strata that are relatively far removed from the boundary. Fossil collections from rocks close to the boundary generally have been made in conjunction with studies of larger scope and reported as faunal lists that are not especially helpful in solving this problem. Consequently the geologist faced with the task of constructing a columnar section for an area of study has usually placed this boundary, with question marks, somewhere "within" or "near" the upper or lower limit of a specified formation.

Field investigations of strata close to the Mississippian-Pennsylvanian boundary at numerous localities in Clark and Lincoln counties, Nevada, during the past five years have resulted in collection of diverse faunas and revealed the lateral persistence of thin "marker" beds over extensive areas that permit detailed correlation of strata within mappable rock units. An analysis of these faunas permits more precise analysis of the ages of rocks close to the boundary than has been possible in the past.

BOUNDARY IN STANDARD AREA

Precise time correlation with the standard sections for Mississippian and Pennsylvanian rocks in the central United States is essential in order to reach valid conclusions concerning placement of this boundary in southern Nevada. Critical areas for study of uppermost Mississippian and lowest Pennsylvanian rocks are in northwestern Arkansas and adjacent Oklahoma (Gordon, 1965), type area for the Morrow Series, and on both sides of the Arbuckle Mountains in south-central Oklahoma (Elias, 1956). In these two regions there was nearly continuous marine sedimentation at the systematic boundary.

The Arkansas sections include Mississippian rocks younger than any in the type Chester (Late Mississippian) of southern Illinois. These uppermost Chester rocks are placed in the *Eumorphoceras bisulcatum* Zone, which is divided into three subzones based on species of *Cravenoceras* (Gordon,

1965). None of the diagnostic genera range into the Morrow (Early Pennsylvanian) in Arkansas, and among 33 genera of Carboniferous ammonoids recognized by Gordon only one, *Gordonites*, crosses the Mississippian-Pennsylvanian boundary. The earliest Pennsylvanian ammonoid zone in Arkansas is the *Glaphyrites globosus* Subzone.

Conodonts are another group of fossils that have promise of effecting long-distance correlation of rocks close to the Mississippian-Pennsylvanian boundary. The conodont sequence is well known in the type Chester (Rexroad, 1957; Rexroad and Collinson, 1961), but there is almost no information on conodonts from lower Pennsylvanian rocks. Genera and species now restricted to the latest Mississippian may, after additional study, be found to range up into Early Pennsylvanian time. The oldest reported Pennsylvanian conodonts are one species from the Wapanucka Limestone (upper Morrow) in Arkansas (Harlton, 1933), and three from the Johns Valley Shale.

Other fossils pertinent to discrimination of the boundary in Arkansas and Oklahoma include the bryozoan genus *Archimedes*. This genus is not known above the Pitkin Limestone (Chester) in Arkansas, or the Goddard Shale in Oklahoma, although it is present in reworked Pitkin cobbles in the basal Hale Formation (Henbest, 1953). In the western United States, however, *Archimedes* ranges up into the Desmoines Series of the Pennsylvanian in Utah. *Pentremites*, while most abundant in the Chester, does occur in the Brentwood Limestone of the Morrow. In the Midcontinent the productoids *Diaphragmus*, *Inflatia*, and *Flexaria* are restricted to Chester rocks.

PREVIOUS ASSESSMENTS OF BOUNDARY IN GREAT BASIN

Formations near the Mississippian-Pennsylvanian boundary in the Great Basin previously have been assigned ages ranging from Devonian through Pennsylvanian, and their age relations have been summarized several times (Moore *et al.*, 1944; Weller *et al.*, 1948; Easton *et al.*, 1953). Recent studies in small areas have necessitated reconsideration of the time relations of some of these formations. Our assessment of ages of stratigraphic units close to the Mississippian-Pennsylvanian boundary in selected areas of the Great Basin, along with that of one author for each area, is shown in Figure 1. We have used the latest author's interpretation of the boundary in all instances because he generally discusses previous placements of the boundary within each area.

From central Nevada to northeastern Utah, Sadlick (1959, 1960, 1963) has

Pennsylvanian		Mississippian	
Chester		Chester	
Morrow		Morrow	
Derry		Derry	
This Study	Bird Spring Formation Indian Springs Formation Chainman Sh. ^{Manning} Battleship Fm.	Spring Mountains, Nevada Longwell and Dunbar, 1936 Bird Spring Formation "Indian Springs Member" M ↓ P ↓	Spring Mts. Lee Canyon, Nevada Rich, 1961 Dunn, 1965 Bird Spring Formation P ↓ M ↓ "Indian Springs Member" M ↓ P ↓
Arrow Canyon, Nevada	Langenheim and others, 1962 "BSc" "BSb" "BS" "Bird Spring Group"	Beaver Dam Mountains, SW Utah Langenheim, 1963 "BSc" "BSb" "BS" "Bird Spring Group"	Pioche, Nevada Sadlick, 1960 Ely Limestone Scotty Wash Quartzite Chainman Shale
Confusion Range, WC Utah	Bissell, 1962 Ely Limestone Scotty Wash Quartzite P. Illipah Fm. M ↓ Chainman Shale	Eureka, Nevada Nolan and others, 1956 Ely Limestone Diamond Peak Quartzite Chainman Shale	Wendover, Nevada Schaeffer, 1960 Ely Limestone Diamond Peak Qtz. Chainman Sh. undifferen- tiated
Quirrh Range, Utah	Sadlick, 1959 Oquirrh Formation Manning Canyon Shale		

Webster and Lane

FIG. 1. Correlation of rock units close to the Mississippian-Pennsylvanian boundary from selected areas in the Great Basin. Abbreviations for Mississippian (M) and Pennsylvanian (P) indicated cited author's placement of the boundary.

shown that, on evidence supplied by goniatites and the *Rhipidomella nevadensis* Zone, the Mississippian-Pennsylvanian boundary must be placed in the upper part of the Diamond Peak, Scotty Wash, Chainman, and Manning Canyon formations. In southern Nevada few goniatites have been

reported, and Rich (1961) placed the boundary within a transition zone at the base of the Bird Spring Formation at Lee Canyon in the Spring Mountains. Langenheim *et al.* (1962) and Langenheim and Langenheim (1965) placed the boundary somewhere within their "BS₁" unit (Indian Springs Formation of this paper) of the Bird Spring Group at Arrow Canyon. Bissell (1962) considered the boundary to be at the base of the Illipah Formation (Indian Springs Formation) in the Spring Mountains, and Brill (1963) placed it in transition beds below the Bird Spring Formation in southern Nevada and below the Ely Limestone in central Nevada and western Utah. Coogan (1964), on the basis of a reported specimen of *Cravenoceras* from Arrow Canyon (Welsh, 1959), drew the boundary at the top of a pebbly unit in the lower part (Indian Springs Formation) of the Bird Spring Formation. Dunn (1965) placed the boundary questionably above a conodont-bearing limestone within the Indian Springs Formation, 90 feet above the Bird Spring-Monte Cristo contact in Lee Canyon. Thus, it is apparent that the only general agreement on the position of this boundary in southern Nevada is that it is somewhere above the Monte Cristo Limestone and below the Bird Spring and Ely formations.

ROCK UNITS NEAR BOUNDARY IN SOUTHERN NEVADA

We recognize the Chainman Shale and the Battleship Wash, Indian Springs, and Bird Spring formations as rock units situated close to or containing the Mississippian-Pennsylvanian boundary within the area of study (Fig. 2).

CHAINMAN SHALE

The Chainman Shale (Spencer, 1917) has been described as a wedge of clastic sediments derived from the west, thickest in central Nevada, and thinning to the east (Sadlick, 1960), characterized by gray to black shale and by an increasing number of thin orthoquartzites and bioclastic limestones in the upper part. In Kane Springs Wash, the unit contains abundant goniatites, the most common of which is *Cravenoceras hesperium*. The Chainman is gradational with the conformably overlying Indian Springs Formation, and its upper limit is drawn arbitrarily at the top of the first orthoquartzite bed below the "marker" conglomerate in the lower Indian Springs.

The orthoquartzites in the upper part of the Chainman probably are correlative with the lower part of the Scotty Wash Quartzite of the Pioche, Nevada, area, although the latter unit is not recognizable in, or south of, Kane Springs Wash. In northern Clark County the Battleship Wash

Formation is correlative with part of the upper Chainman. The facies change between Chainman black shales and Battleship Wash limestones is exposed in the Meadow Valley range about 10 miles south of Kane Springs Wash.

BATTLESHIP WASH FORMATION

The Battleship Wash Formation, called "BS_a" unit by Langenheim *et al.* (1962), was subsequently named as a formal stratigraphic unit (Langenheim and Langenheim, 1965). The unit is a resistant, bluish-gray weathering limestone that contains *Faberophyllum* sp. and *Striatifera brazeriana* (Girty), suggesting correlation with the Great Blue Formation (lower Chester) of central Utah. The uppermost 3 feet of the Battleship Wash contain a late Chester conodont fauna consisting of, among others, *Cavusgnathus*, *Gnathodus*, *Spathognathodus*, and *Magnilaterella* that is similar to late Chester conodonts of the Illinois Basin. The uppermost bedding surface of the formation in Arrow Canyon yields rare specimens of *Rhipidomella nevadensis* (Meek), the lowest occurrence of this diagnostic species we have found in southern Nevada.

The Battleship Wash Formation has not been recognized to the south or southeast in the Spring or Muddy Mountains in Clark County, although it is included in the Bird Spring Group by Langenheim and Langenheim (1965). Because the lithology is distinctive, the fauna is different, and the age is Late Mississippian, we consider the Battleship Wash to be a separate formation not included in, or related to, rocks of the Bird Spring or Indian Springs formations at their type localities.

INDIAN SPRINGS FORMATION

The Indian Springs Member, as originally defined, included the lowest 700 feet of the Bird Spring Formation and was believed to be of formational rank (Longwell and Dunbar, 1936), lying between the Monte Cristo Limestone below and the *Fusulinella* Zone above. The member was thought to be, at least in part, of Chester age, as indicated by a study of megafossils by Girty (Longwell and Dunbar, 1936, p. 1203). Langenheim and Langenheim (1965) advocate abandoning the name Indian Springs because it is preoccupied by Indian Spring Sandstone (Silurian) of Maryland (Swartz, 1923) and Indian Springs Shale (Chester) of Indiana (Malott and Thompson, 1920). We judge that the Maryland usage is distant enough, both geographically and temporally, for no confusion to result from retention of the name in Nevada, and the unit name in Indiana has been officially abandoned by the Indiana Geological Survey. Therefore we are retaining the name Indian

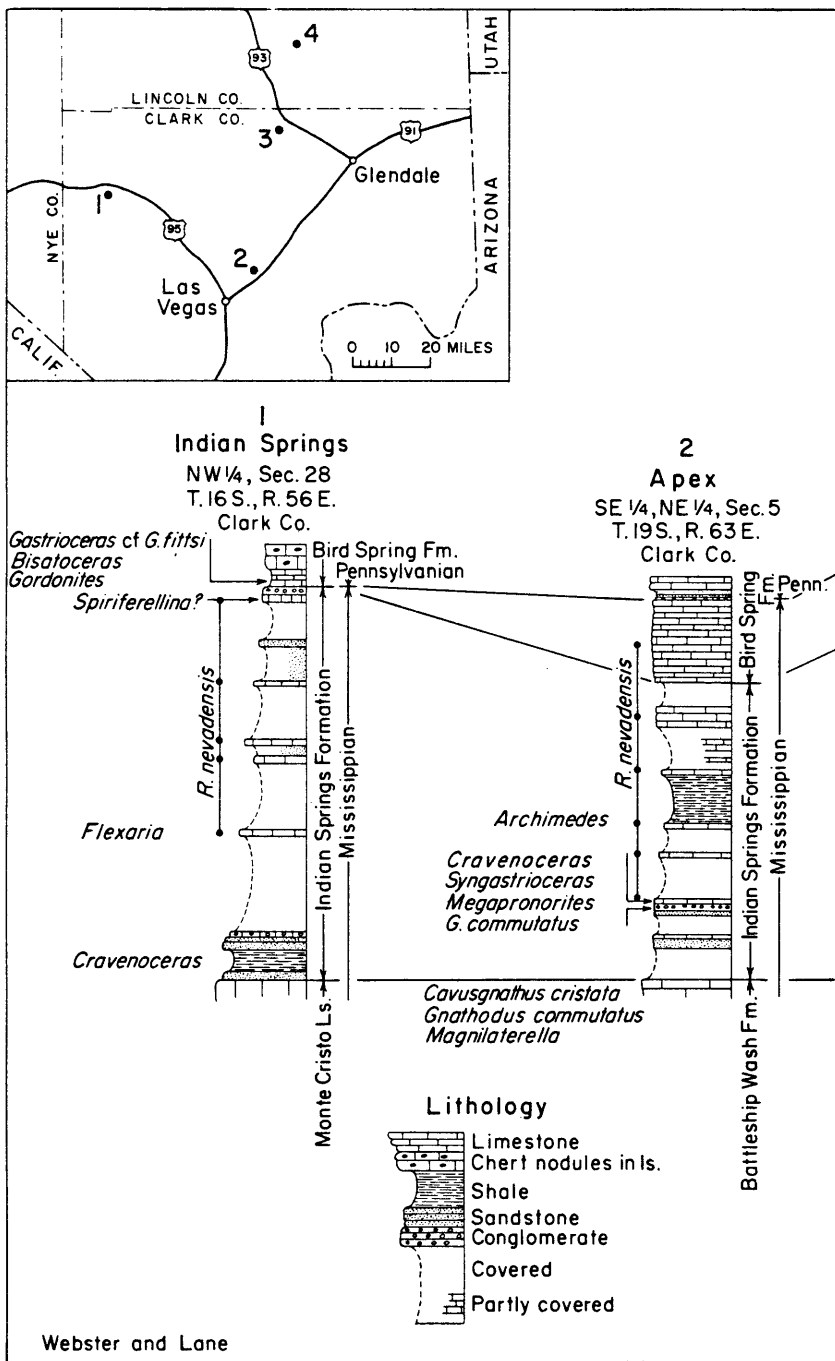
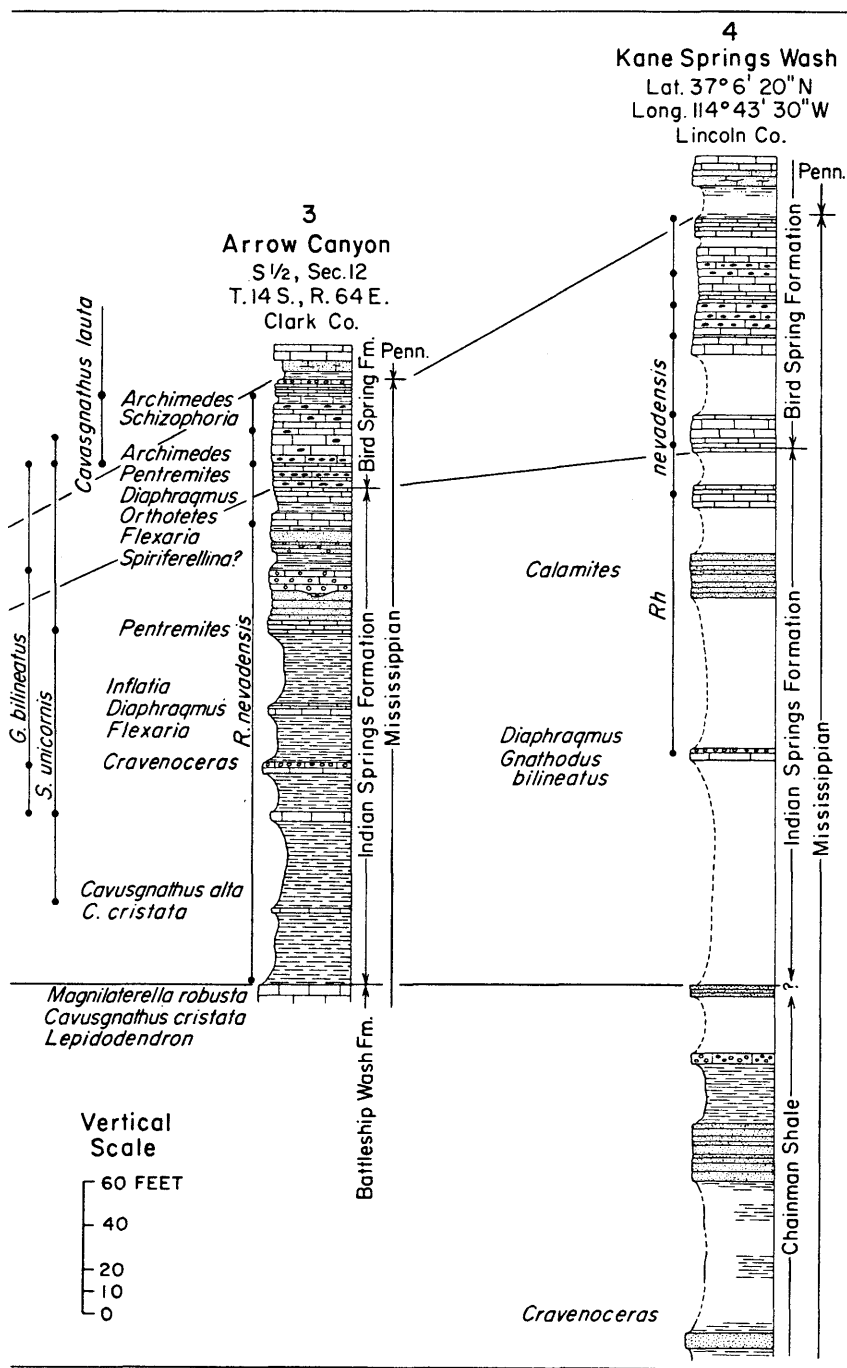


FIG. 2. Correlation of rocks close to the Mississippian-Pennsylvanian

Springs, as it is the earliest appropriate name for this rock unit in southern Nevada.

The Indian Springs is here removed from the Bird Spring Formation,



boundary in southern Nevada. (For "Megapronorites" read "Pronorites.")

raised to formational rank, and restricted to red-weathering thin-bedded shale, sandstone, and limestone exposed in a persistent strike valley throughout the area of development (Fig. 2). Lithologically the Indian Springs is domi-

nantly black shale that is mostly covered, with locally exposed red and green shales, thin bioclastic limestones, and clean orthoquartzites in the lower two-thirds, grading upward into red-weathering ferruginous limestones with subordinate shale, orthoquartzites, and conglomerates. The lower boundary is the top of the Battleship Wash, or Chainman, Formation, or, where these are absent, Monte Cristo Limestone. The upper boundary is marked by lowest gray-weathering, thick-bedded limestones of the Bird Spring Formation.

A persistent limestone that includes dark, red-weathering, ferruginous chert-pebble conglomerate in the upper part is present just below the middle of the formation at all outcrops north of Las Vegas Valley as far as Kane Springs Wash. This bed is here referred to as the "marker" conglomerate, and, in the Apex Section (Fig. 2), it is directly overlain by a bed containing cephalopods described here that are judged to be of Late Mississippian age.

In the type area of the Indian Springs the marker conglomerate has not been found and exact placement of the Mississippian-Pennsylvanian boundary must remain uncertain until the conodonts have been studied. One specimen of *Cravenoceras* was found in the lower 20 feet of the type Indian Springs, and the lowest foot of the Bird Spring Formation has yielded a well-preserved upper Morrow conodont and cephalopod fauna that includes *Gastrioceras* cf. *G. fittsi* Miller and Owen, *Bisatoceras*, *Gordonites*, *Polygnathodella*, and *Idiognathodus*. Consequently the systematic boundary clearly lies within the type section of the Indian Springs Formation. Conodonts associated with these goniatites indicate that the basal Bird Spring Formation in the type Indian Springs area is equivalent to beds at least 320 feet above the base of the Bird Spring in Arrow Canyon. Consequently, to the north, a para-conformity between these two formations at Indian Springs either is absent or represents a considerably shorter time span.

Substitution of the name Illipah Formation for the Indian Springs in southern Nevada (Bissell, 1962) is rejected because the lithologies of the two formations are quite different and the Illipah has been considered a synonym of the Scotty Wash Quartzite (Steele, 1960), in which we concur. Langenheim *et al.* (1962) suggest that their units "BS_a" and "BS_b" are equivalent to the Indian Springs but do not use the latter term. Their "BS_b" is equivalent to the Indian Springs as restricted here and their "BS_a" unit has since been named the Battleship Wash Formation.

BIRD SPRING FORMATION

Only the lower part of the Bird Spring Formation that encloses the upper *Rhipidomella nevadensis* Zone is included in this discussion (Fig. 2). The Bird Spring ranges in thickness from 2500 to possibly 7000 feet and consists of predominantly bioclastic limestone interbedded with arenaceous and

argillaceous limestone, thin, fine-grained sandstone, and shale. Some cherty limestone beds are distinctive and can be used locally as marker beds.

Comparison of the Bird Spring Formation (Hewett, 1931) with the Callville Formation (Longwell, 1928) is outside the scope of this study. In its type area near Goodsprings, Nevada, the Bird Spring is more closely similar to the Callville than it is in sections farther north and west with which this report is concerned. Lowest Bird Spring beds that enclose the *R. nevadensis* Zone in northern Clark and southern Lincoln counties are absent in the type area, as they are in the Callville area to the east. Our study of these two formations indicates that there are no distinctive lithologic changes within either formation that allow division into mappable members, although zonal units based on fossils are possible, and potentially useful; no laterally persistent mappable break at the Pennsylvanian-Permian boundary can be recognized on lithologic grounds independent of fusulinid identifications; and major differences between the two formations are that the Callville is thinner, contains a greater proportion of algal and arenaceous limestones, and weathers brownish-gray rather than gray. Therefore we believe that the Callville should be regarded as shelf deposits to the east of the Las Vegas hinge line and the Bird Spring as trough deposits west of that line.

FAUNA PERTINENT TO THE PROBLEM

INTRODUCTORY REMARKS

In many parts of North America the distinction between Mississippian and Pennsylvanian rocks is clear-cut and there is little difficulty concerning placement of this systemic boundary. Concerning the Midcontinent Moore *et al.* (1944, p. 663) wrote that "sections in which the Mississippian-Pennsylvanian boundary is obscure are few," but this statement clearly does not apply to southern Nevada.

Placement of this boundary in the central United States, based on paleontological evidence, has been reviewed by Mather (1915) for the Morrow Series, Easton (1943) for the Pitkin Limestone, and Elias (1956) for the "Springer Series." All of these authors place at least some reliance on the bulk aspect of the respective faunas, generally stated in terms of the relative numbers of genera and species that exhibit close relationships with antecedent Mississippian fossils or descendant Pennsylvanian types.

Concerning the specific correlation problem under discussion, the fauna of the Indian Springs Formation and the *Rhipidomella nevadensis* Zone, we would have to conclude that, because of the gross aspect of their fossils, these units should be assigned entirely to the Mississippian System. The various productoids and other brachiopods, including *R. nevadensis* (Meek),

are assignable either to genera that have been reported exclusively from the Mississippian, like *Flexaria*, *Inflatia*, and *Diaphragmus*, or to species that are most similar to antecedent Mississippian forms, like *R. nevadensis*. In addition the Indian Springs *Archimedes* and *Pentremites* are more like Mississippian than Pennsylvanian species, although the genera are present in both systems.

The cephalopod fauna described here occurs stratigraphically below all of the fossils with Mississippian affinities listed above. Two of the goniatites, *Syngastrioceras walkeri* n. sp., and *Pronorites* sp., when compared with goniatites presently known from the Midcontinent, are much more like Pennsylvanian than Mississippian species. Consequently, serious consideration was given to the hypothesis that the upper part of the Indian Springs Formation and the *Rhipidomella nevadensis* Zone might be Pennsylvanian in age. But descriptions of *Syngastrioceras* (as *Eoasianites*) and *Pronorites* from rocks confidently assigned to the *Eumorphoceras bisulcatum* (E₂) Zone of Spain and Yugoslavia, indicate that these goniatites do occur in rocks correlative with the Chester Series of North America.

ECHINODERMS

One crinoid, *Parulocrinus vetulus*, and one blastoid, *Pentremites crystalensis*, are the only reported echinoderms from strata near the Mississippian-Pennsylvanian boundary in southern Nevada. Lane (1964) records *Parulocrinus vetulus* Lane associated with *Pentremites* and *Archimedes* from brown-weathering limestones (uppermost part of the Indian Springs Formation here) in the upper part of the *Rhipidomella nevadensis* Zone at Arrow Canyon; he considers it to be Morrow in age. Macurda (1964) described *Pentremites crystalensis* from a bed approximately 250 feet above the base of the Bird Spring Formation at Crystal Springs, Nevada. He assigned a Pennsylvanian age to the species but considered it to be most similar to middle and late Chester species of the Midcontinent. Webster collected topotype material of *P. crystalensis* Macurda from a ferruginous yellow-brown weathering limestone in the upper part of the Indian Springs Formation. We have found *P. crystalensis* to be locally abundant in exposures of the uppermost Indian Springs and basal Bird Spring at numerous localities from Kane Springs Wash to Gass Peak.

Additional crinoids and blastoids discovered by us in the upper part of the Indian Springs Formation in the Arrow Canyon Range have been identified as new species of *Aesiocrinus*, *Plummericrinus*, *Pentremites*, and a genus of pirasocrinids. Specimens of the first three genera occur in a shale unit below the occurrence of *Pentremites crystalensis* and above the "marker" conglomerate. Neither *Aesiocrinus* nor *Plummericrinus* has been reported

from rocks older than Pennsylvanian. The two specimens judged to be pirasocrinids are too poorly preserved for generic assignment; they were found with associated *Pentremites crystalensis*. The pirasocrinids range from Mississippian through Permian but are most abundant in the Pennsylvanian.

Because of presence of three crinoid genera (*Aesiocrinus*, *Parulocrinus*, and *Plummericrinus*) that have been reported only from rocks of Pennsylvanian and younger age in the Midcontinent, the age of the upper part of the Indian Springs Formation could be Pennsylvanian. However, associated species of *Pentremites* are most closely allied to Mississippian species.

BRACHIOPODS

The Battleship Wash Formation of Chester age is characterized especially by *Striatifera brazeriana* (Girty), locally abundant in the Arrow Canyon and Meadow Valley ranges. The Indian Springs Formation contains a diverse brachiopod assemblage, dominated by the zonal name-giver *Rhipidomella nevadensis*. This large dalmanellid is abundant in limestones, where it is commonly silicified, and in calcareous shales. The species is most similar to Mississippian species like *R. oweni* Hall and Clarke and is quite unlike the small, Pennsylvanian *R. carbonaria* (Swallow) of the Midcontinent, or the closely allied Nevada Pennsylvanian species *R. elyensis* Lane, which occurs higher in the Bird Spring Formation. Associated with *R. nevadensis* are the productoids *Flexaria*, *Inflatia*, and *Diaphragmus phillipsi* (Norwood and Pratten), a small *Canocrinella*-like linoproductid, *Anthracospirifer*, *Schizophoria*, *Orthotetes*, and a large ?*Spiriferellina*. The first three productoids are abundant to common and represented by numerous brachial valves showing internal features that allow identification. All three are restricted to Chester rocks of the Midcontinent and range through the *R. nevadensis* Zone in southern Nevada. No brachial interiors of the small *Canocrinella*-like linoproductid have been seen, but this species is externally similar to *C. boonensis* (Swallow), which is restricted to Pennsylvanian age rocks. The *Schizophoria* is large and transverse and resembles the Mississippian *S. swallowi* (Hall) and the Pennsylvanian *S. resupinoides* (Cox), but is quite unlike smaller, subquadrate *S. texana* Girty of younger Morrow rocks in southern Nevada (Lane, 1963). Fragmentary, or poorly preserved, specimens of this large *Schizophoria* somewhat resemble *R. nevadensis* (Meek) externally because of comparable ornament, but even fragmentary interiors of either valve provide clear distinction between the coexisting forms.

Specimens of *Orthotetes occidentalis* Lane from the *R. nevadensis* Zone are similar, externally and internally, to the type specimens from Morrow age rocks in the Spring Mountains.

There are several punctate spiriferinid brachiopods in the Indian Springs

and Bird Spring formations that may prove of zonal value. The *R. nevadensis* Zone is characterized by a relatively large, generally silicified species that has abundant close-spaced tubercles and lacks strong, imbricating growth lamellae characteristic of *Punctospirifer*, a genus which has been found only in the Middle Pennsylvanian and younger parts of the Bird Spring Formation. Faunal lists of the *R. nevadensis* Zone commonly include *Reticulariina spinosa* (Norwood and Pratten), but we have found definitely spinose spiriferinids restricted to the Morrow part of the Bird Spring, and the older, larger, tuberculate species is assigned provisionally to *Spiriferellina* and may be conspecific with "*Spiriferina*" *gonionota* Meek from Railroad Canyon, Nevada, the type locality of *Rhipidomella nevadensis*.

In summary, most brachiopods range through the *Rhipidomella nevadensis* Zone and have closer Mississippian than Pennsylvanian affinities.

BRYOZOANS

Although a wide variety of bifoliate, massive, ramose, and fenestrate bryozoans can be found in rocks under discussion, only one genus, *Archimedes*, has been studied by us. Specimens are moderately common in limestones of the upper Indian Springs Formation, but most consist of shafts without attached fenestrate expanse. At least two varieties of shafts are present, one like *Archimedes* cf. *A. pseudoswallovanus* Elias previously reported from the Indian Springs (Lane, 1961), and another, more slender shaft with more widely spaced volutions that resembles *Archimedes distans* Ulrich from the Chester or *A. gillulyi* Condra and Elias of the Oquirrh (Desmoines) of Utah. Although no definitely Pennsylvanian species of *Archimedes* have been found in the standard area, well-documented Desmoines species are known from Utah.

CONODONTS

In the Midcontinent, conodonts have proved to be of value for correlation of Upper Mississippian formations, whereas little work has been done on Lower Pennsylvanian forms. The only conodont fauna close to the boundary so far described from southern Nevada (Dunn, 1965) is judged to be of late Chester age. Webster has obtained nearly 12,000 conodonts from the uppermost bed of the Battleship Wash Formation through the Derryan part of the Bird Spring Formation at six sections in northern Clark and southern Lincoln counties. Study of this collection reveals a moderate faunal break between the Battleship Wash and Indian Springs formations and a distinct break coinciding with the top of the *Rhipidomella nevadensis* Zone, within the lowest Bird Spring Formation; it also suggests that the most complete Late

Mississippian to Early Pennsylvanian conodont faunal succession in North America may occur in the Great Basin.

Magnilaterella robusta Rexroad and Collinson and *Spathognathodus campbelli* Rexroad were not found above the Battleship Wash Formation; both indicate a Chester age for the upper part of that formation (Fig. 2). *Cavusgnathus cristata* Branson and Mehl was not found above the lower third of the Indian Springs Formation, and the appearance of *C. navicula* (Hinde) and *Streptognathodus unicornis* Rexroad and Burton in the lower part of the Indian Springs suggests a late Chester age for its lower half.

The fauna of the upper part of the Indian Springs and basal Bird Spring grossly resembles that of the lower Indian Springs; but *Cavusgnathus navicula* was not found above the Indian Springs, and additional species of *Streptognathodus* and *Cavusgnathus*, including "*C.*" *muricata* Dunn, appear. Age assignment of this part of the section, based on the overall similarity of the fauna to described Late Mississippian faunas of the Midcontinent, should be considered latest Chester.

Thus the conodonts indicate a Chester age for the upper part of the Battleship Wash Formation, the Indian Springs Formation, and the basal Bird Spring Formation.

CEPHALOPODS

In central and northern Nevada Mississippian cephalopods have been reported from the Chainman Shale by several authors. Only one cephalopod, *Cravenoceras* sp., has been reported from the lower part of the Indian Springs Formation at Arrow Canyon (Welsh in Coogan, 1964) in southern Nevada. Our field studies revealed the presence of two cephalopod-bearing beds near the middle of the Indian Springs Formation.

The lower horizon is the "marker" conglomerate and is widespread throughout the area. It contains the following cephalopods (number of specimens in parentheses): *Cravenoceras* sp. A (3); *Cravenoceras* sp. B (9); unidentified subdiscoid goniatite (1). Specimens of *Cravenoceras* sp. A are fragmentary and were found at Arrow Canyon, the Las Vegas Range, and the southern end of the Arrow Canyon Range. *Cravenoceras* sp. B is small and was found at Arrow Canyon and the Las Vegas Range. The unidentified subdiscoid goniatite was found at Arrow Canyon. All specimens are poorly preserved, consisting mostly of ferruginous material. The abundance of *Cravenoceras* suggests a Chester age for the fauna.

The upper bed is a limestone directly above the "marker" conglomerate at the Apex locality. It yielded the following fauna: *Mooreoceras* sp. (25); *Liroceras liratum* (Girty) (14); *Syngastrioceras walkeri* Webster and Lane, n. sp. (35); *Pronorites* sp. (2); *Cravenoceras* sp. (1).

Preservation of this fauna is good to excellent, and although most specimens are distorted, sutures are well preserved. The presence of *Cravenoceras*, represented by a single immature specimen, possibly belonging to *C. merriami* Youngquist, is indicative of a late Mississippian age. Although pronoritids are much more common in Pennsylvanian than Mississippian rocks, *Megapronorites* has been reported from the E₂ Zone of Spain (Kullman, 1962a), and *Pronorites* from the same zone in Yugoslavia (Kullman, 1962b). Abundant specimens of *Syngastrioceras walkeri* n.sp., similar to some Morrow species generally reported as *Eoasianites*, might be considered indicative of an early Pennsylvanian age, if only North American goniatite faunas are considered. But species of *Eoasianites* described from the *Eumorphoceras* Zone of Spain and Yugoslavia (Kullman, 1962a, 1962b; Wagner-Gentis, 1963) may be congeneric with the Nevada species. Thus, goniatites of this type do occur in rocks that can be correlated confidently with the Chester Series.

SUMMARY

We conclude that the Mississippian-Pennsylvanian boundary in southern Nevada is properly placed at the top of the *Rhipidomella nevadensis* Zone. The zone is confined to the Indian Springs Formation south of Las Vegas Valley, in the Indian Springs type area, but ranges into the lowest Bird Spring Formation in northern Clark County. Although some faunal elements of the zone, like the crinoids, have close Pennsylvanian affinities, most fossils are of decidedly Mississippian aspect. The upper boundary of the *Rhipidomella nevadensis* Zone coincides with a notable change in both megafossils and conodonts that is interpreted here to represent the systematic boundary in this area.

SYSTEMATIC PALEONTOLOGY

Measurements and conch forms are in accord with Gordon (1965, p. 87). All type specimens as well as listed specimens bear catalogue numbers of the Invertebrate Paleontology Collections, Department of Geology, University of California, Los Angeles. Negatives of photographs are on file in the same department.

Genus *Liroceras* Teichert, 1940

Liroceras liratum (Girty, 1911)

Fig. 4, *f*, *j*, *k*, *l*

Remarks.—Two specimens of *Liroceras liratum* from the Apex locality are illustrated. The smaller shows spiral ornamentation, the larger size and form of the species.

Types.—Hypotypes, UCLA 39478 and 39477.

Genus *Cravenoceras* Bisat, 1928

Cravenoceras sp.

Fig. 3, *a*; 4, *c*, *d*

Remarks.—A single distorted specimen is identified as *Cravenoceras* sp. Because the specimen probably represents an immature individual, no specific identification was attempted.

Types.—Hypotype, UCLA 39481.

Genus *Pronorites* Mojsisovics, 1882

Pronorites sp.

Fig. 3, *b*, *c*; 4, *a*, *b*, *e*, *h*

Description.—Shell discoidal; venter flat and flanks slightly convex to straight in mature whorls; umbilicus wide (approximately one-fourth shell width) in youthful stages, unknown at maturity; suture with 3 or 4 lateral lobes at maturity.

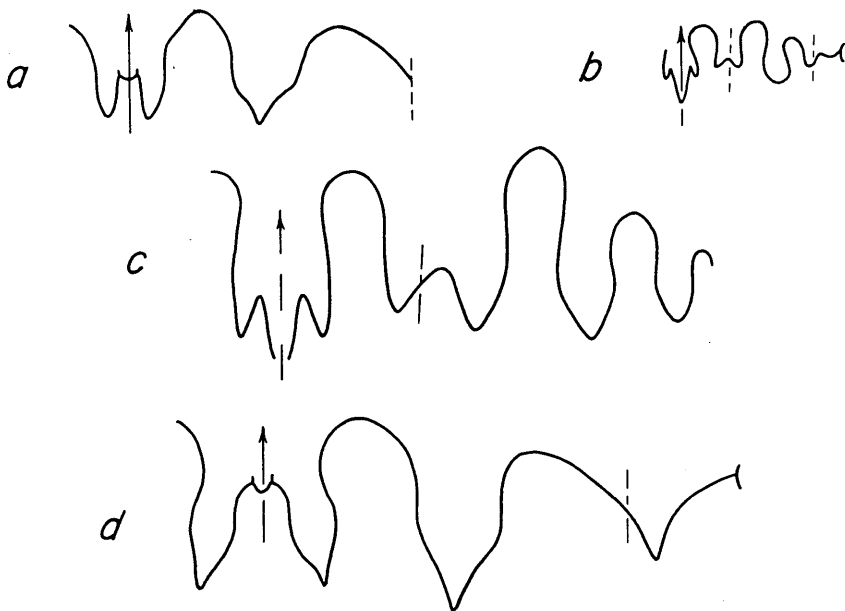


FIG. 3. Sutures of Late Mississippian ammonoids from southern Nevada. *a*, *Cravenoceras* sp., UCLA 39481, at diameter of 10 mm., $\times 5$; *b*, *c*, *Pronorites* sp., *b*, UCLA 39480, at diameter of 8.3 mm., $\times 5$; *c*, UCLA 39479, at whorl width of 7.6 mm., height of 8.8 mm., $\times 5$; *d*, *Syngastrioceras walkeri* Webster and Lane, n. sp., holotype, UCLA 39482, diameter of 39 mm., $\times 3$.

The larger hypotype is a fragmentary shell with parts of two whorls preserved. The smaller hypotype is an immature specimen of which the last whorl is approaching the same size and stage of development as the inner whorl of the larger specimen. In early stages the shell has a moderately convex venter which flattens with maturity. The flanks are evenly convex in early whorls and slightly convex to subparallel in later whorls. The umbilicus is wide in early stages, slightly over one-fourth the shell diameter; this ratio is unknown in later whorls. The umbilical shoulder is rounded early, tending to become subangular later.