THE BIRD SPRING GROUP, CHESTERIAN THROUGH WOLFCAMPIAN, AT ARROW CANYON, ARROW CANYON RANGE, CLARK COUNTY, NEVADA

V. A. M. LANGENHEIM AND R. L. LANGENHEIM, JR.
401 W. Vermont, Urbana, and University of Illinois, Urbana

ABSTRACT. — Approximately 3500 feet of Chesterian through Wolfcampian rock exposed in Arrow Canyon are assigned to the Bird Spring Group. At this locality the group comprises five units of formational rank: The Battleship Wash Formation—80 feet of cliff-forming limestone of Chesterian age, the BSb unit—240 feet of shale and sandy limestone of probable Springeran age, the BSc unit—2200 feet of limestone and cherty limestone of Springeran (?) through Missourian age, the BSd unit—320 feet of interbedded limestone and shaly limestone of Missourian, Virgilian and Wolfcampian age, and the BSe unit—530 feet of dolomite and limestone of Wolfcampian age.

The following description of the Late Paleozoic cyclic limestone sequence at Arrow Canyon is part of a continuing project to furnish a reference section for Late Cambrian through Permian rocks in the southern part of the Cordilleran miogeosyncline. Detailed description of the entire Bird Spring Group exposed in this locality should provide a useful datum for investigators considering regional Late Paleozoic stratigraphy and establish stratigraphic relationships of previously described invertebrate fossils (McCutcheon and Wilson, 1961, 1963; Wilson, 1963; Wilson, Waines and Coogan, 1963).

Arrow Canyon is superposed across the northern end of the Arrow Canyon Range approximately 50 miles N. E. of Las Vegas, Nevada (Fig. 1). Certain strata well-exposed in the walls of this canyon range in age from Late Mississippian to Permian and have been placed within the Bird Spring Group.

Procedure. — Stratigraphic sections were measured by tape and compass and traverse data were reduced to stratigraphic thickness with the aid of Mandelbaum and Sanford's (1952) tables. Representative samples were collected from each separately described bed and field descriptions are supplemented by study of polished sections and insoluble residues. Selected fusulinids have been identified for stratigraphic control and only a few of the more prominent or stratigraphically significant larger invertebrates have been studied.

STRATIGRAPHY

Previous Work. — Spurr (1903) first reported Carboniferous rocks at the northern end of the Arrow Canyon Range, but referred to the mountains as the Meadow Valley Range. Longwell (1928, 1949, 1952) briefly mentioned these rocks, but noted in particular the excellent exposures in Arrow Canyon. Later, Bowyer, Pampeyan and Longwell (1958) showed the distribution of Pennsylvanian and Permian rocks on a geologic map of Clark County. Stratigraphic studies by Bissell (1962b, c) refer to, but do not describe sections in the Arrow Canyon Range. Brill (1963, Fig. 14) presented a generalized columnar sec-

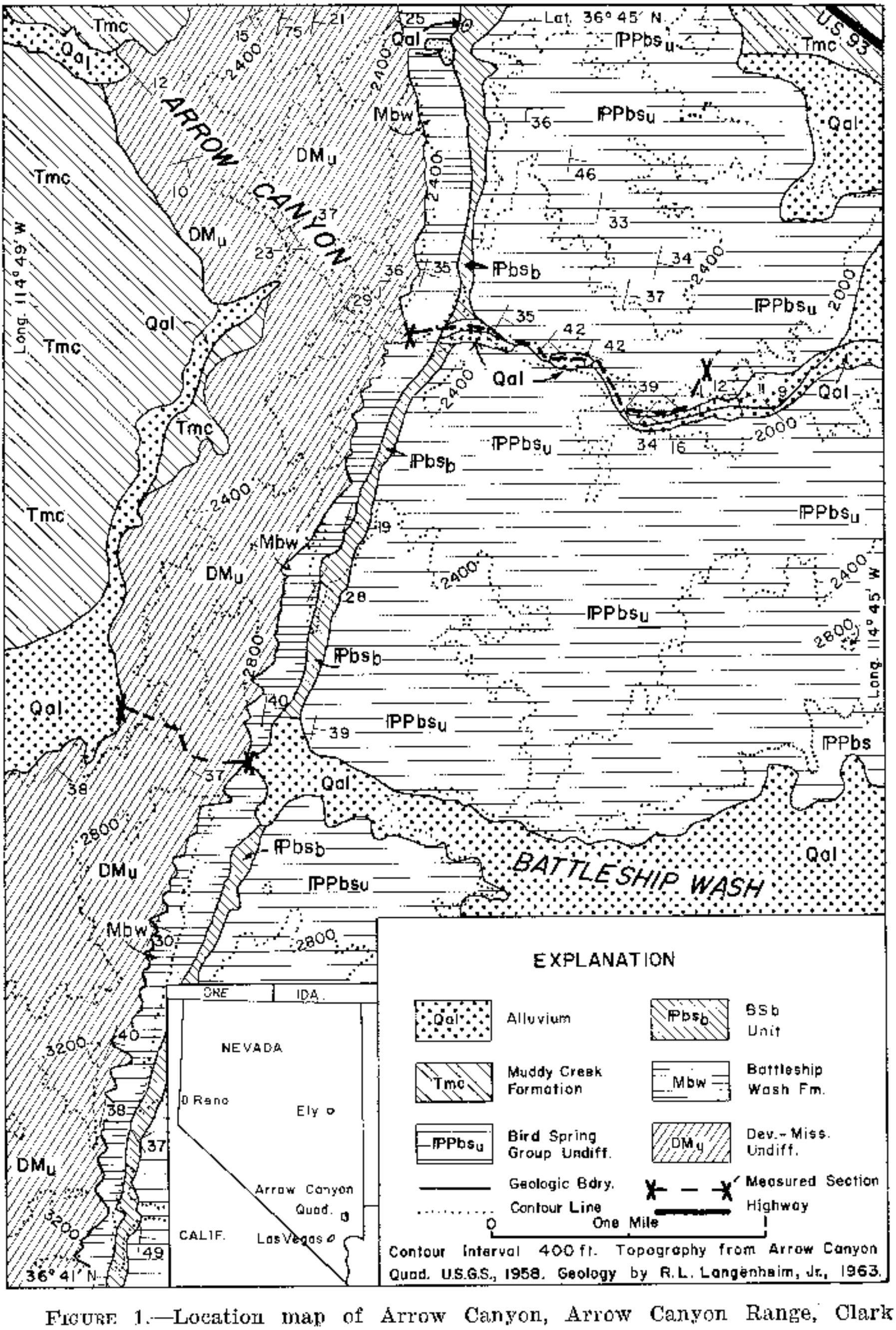

FIGURE 1.—Location map of Arrow Canyon, Arrow Canyon Range, Clark County, Nevada.

tion of the strata in question and a short discussion of their aspect and fauna. Coogan (1964) has provided a more detailed description of the Chesterian through mid-Atokan portion of the sequence. Other pertinent studies have been reported by Langenheim et al. 1962), McCutcheon and Wilson (1961), Wilson, Waines and Coogan (1963), and, in unpublished theses, by Duley (1957), Welsh (1959), Coogan (1962) and V. A. M. Langenheim (1964).

Stratigraphic Nomenclature. — Longwell (1921, 1928 described Pennsylvanian and Permian rocks in the Muddy Mountains, and assigned them to the Callville Limestone, whereas Glock (1929) employed the name, "Bird Spring", for similar rocks in the Spring Mountains. Later, the Bird Spring Formation was described by Hewett (1931) in greater detail. These formation concepts, as erected, distinguish strata between the cliff-forming Mississippian rocks of the region and redbeds identified as the "Supai" Formation (Fig. 2). Although the Callville concept enjoys priority, we prefer to refer the Arrow Canyon rocks to the Bird Spring Formation because its original description is more complete, because there are no doubts concerning the precise limits of its application in the type area, and because it has been employed by most workers in the area.

In addition to these two formational concepts, applicable to the entire sequence, several less inclusive units have been proposed. Longwell (1921, 1928) defined as the Blue Point Limestone a cliff-forming limestone containing a "Brazer fauna". This unit incorporates beds between the overlying Callville Limestone and the Lower Mississippian Rogers Spring Limestone, but was mapped by Longwell as part of an undivided sequence with the Rogers Spring Limestone. Longwell (personal communication, 1955) has since suggested that the Blue Point Limestone may be equivalent to some part of the Indian Springs Member of the Bird Spring Formation. Examination of sections in the Muddy Mountains (Langenheim, 1956), however, failed to locate fossils clearly identical to those reported by Longwell, and Longwell's original collections appear to have been lost or mislaid in the collections of the U. S. Geological Survey. As a consequence, the Bluepoint Limestone could possibly be correlated with either the Indian Springs Member or with the uppermost Monte Cristo Formation of most authors.

Longwell and Dunbar (1936) recognized a Chesterian faunal assemblage in the lowermost, shaly portion of the Bird Spring Formation in the type area. On this basis, they assigned these rocks to what they called the Indian Springs Member of the Bird Spring Formation. The name, "Indian Springs," however, is preoccupied by the Indian Spring Shale and the Indian Spring Redbeds, Silurian of Maryland (Swartz, 1923) and by the Indian Springs Shale, Chesterian of Indiana (Malott and Thompson, 1920). We recommend abandonment, therefore, of the name, "Indian Springs", for the Chesterian, lowermost member of the Bird Spring Formation of southern Nevada.

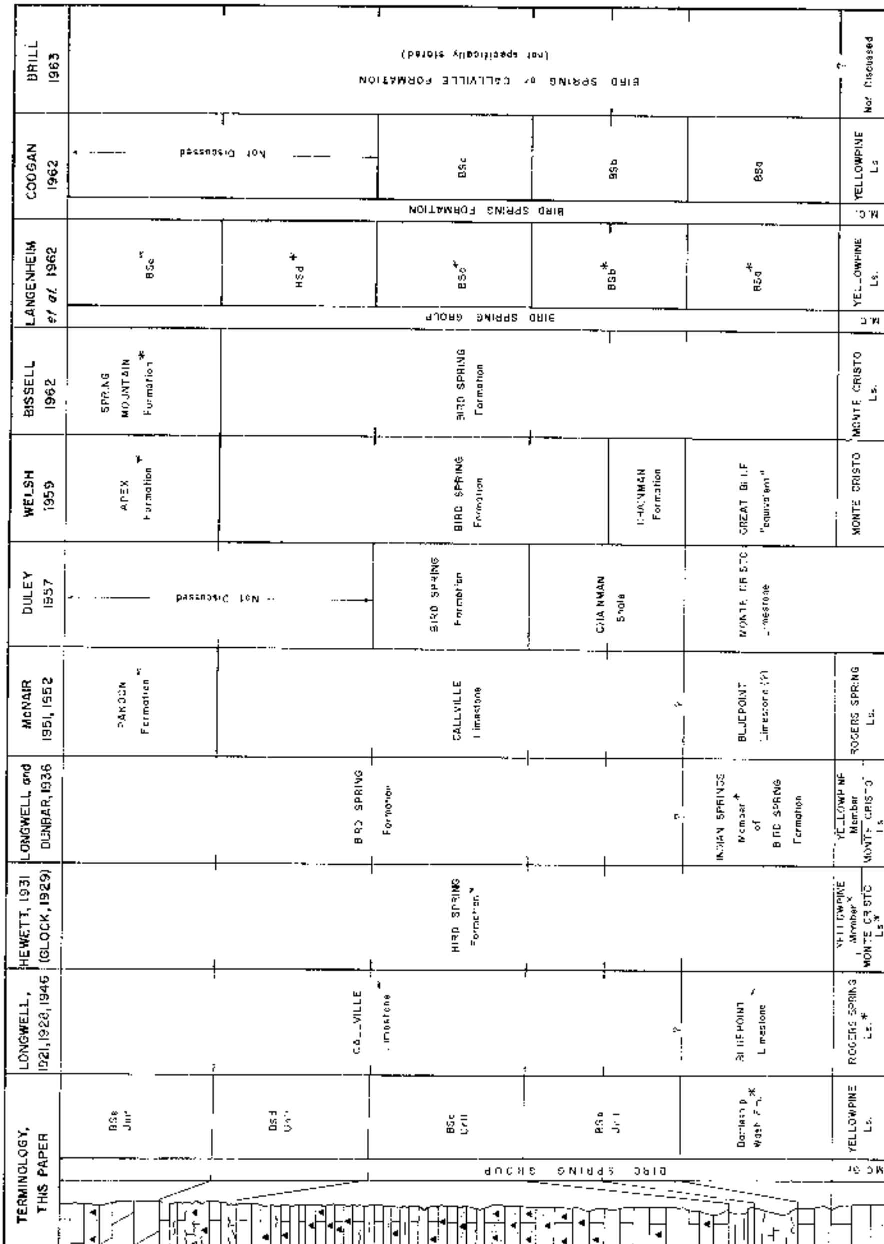

FIGURE 2.—Chart showing stratigraphic nomenclature applied to late Paleozoic rocks of southern Nevada. An asterisk indicates the original description of a unit.

Permian rocks, originally included in the Callville Limestone or Bird Spring Formation, have been assigned by certain investigators to separate formational units. McNair (1951) has defined the Pakoon Formation as consisting of dolomitic, Permian rocks, formerly included in the Callville Formation, cropping out in northwestern Arizona and adjacent areas. The Spring Mountain Formation, defined by Bissell (1962b, c), includes Wolfcampian and Leonardian rocks formerly included in the Bird Spring Formation.

Welsh's (1959) more elaborate classification includes separate Pennsylvanian and Permian formations in both a basinal and platform facies within Clark County. The Callville and Pakoon Formations, in the sense of McNair (1951), are recognized as the platform facies, the Bird Spring Formation is restricted to Pennsylvanian rocks in the basinal facies and a new formation, the Apex Formation, is proposed for Permian rocks in the basinal facies.

We (Langenheim et al., 1962; Langenheim, V. A. M., 1964) have subdivided the Bird Spring Formation into locally useful units, BSa through BSe. The BSa unit is of the proper lithology, age, and stratigraphic position for assignment to the Blue Point Limestone, but the latter was not adequately defined and definite correlation appears to be impossible. The BSa and BSb units together probably constitute the "Indian Springs Member" as described by Longwell and Dunbar (1936). Doubt remains, however, as to whether the tops of the BSb unit and the Indian Springs Member are to be correlated. Perhaps all or part of the BSb unit should be more properly assigned to the White Pine Group in either the Chainman Shale or Hamilton Canyon Formation. The BSc and BSd units together are roughly equivalent to the restricted Bird Spring Formation of Bissell (1962b, c) or Welsh (1959), and the BSe unit approximates the Pakoon Formation of McNair (1951), the Spring Mountain Formation of Bissell (1962b, c) or Apex Formation of Welsh (1961). Differences between the bounding limits appear, however, because the Pennsylvanian-Permian boundary apparently lies within the BSd unit at a horizon not readily recognizable for mapping purposes.

Except for the BSa unit, we have as yet not adequately demonstrated the other informal units to be readily useful in mapping, and, for this reason, we prefer not to propose them as formational units. The BSa unit, however, has a distinctive lithology and serves as a useful map unit throughout its extent in the Arrow Canyon Quadrangle. For these reasons we are formally designating it the Battleship Wash Formation of the Bird Spring Group.

Descriptive Stratigraphy (Figs. 3, 4). – In Arrow Canyon the Bird Spring Group is approximately 3500 feet thick and is almost entirely of limestone with the exception of one prominent dolomite interval about 300 feet thick near the top and approximately 240 feet of predominantly shaly rocks near the base. Portions are abundantly cherty.

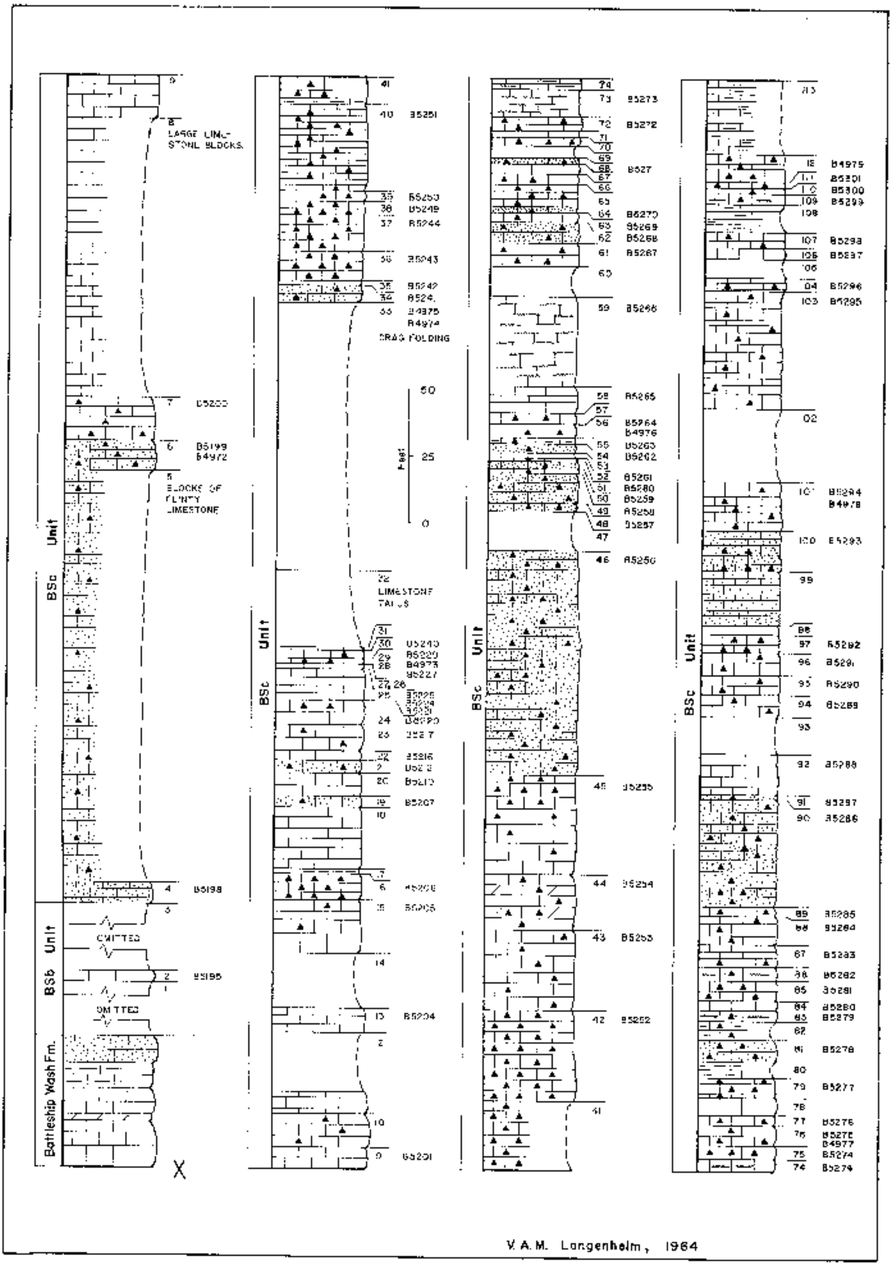

FIGURE 3.—Columnar section of the lower portion of the Bird Spring Group as exposed in Arrow Canyon.

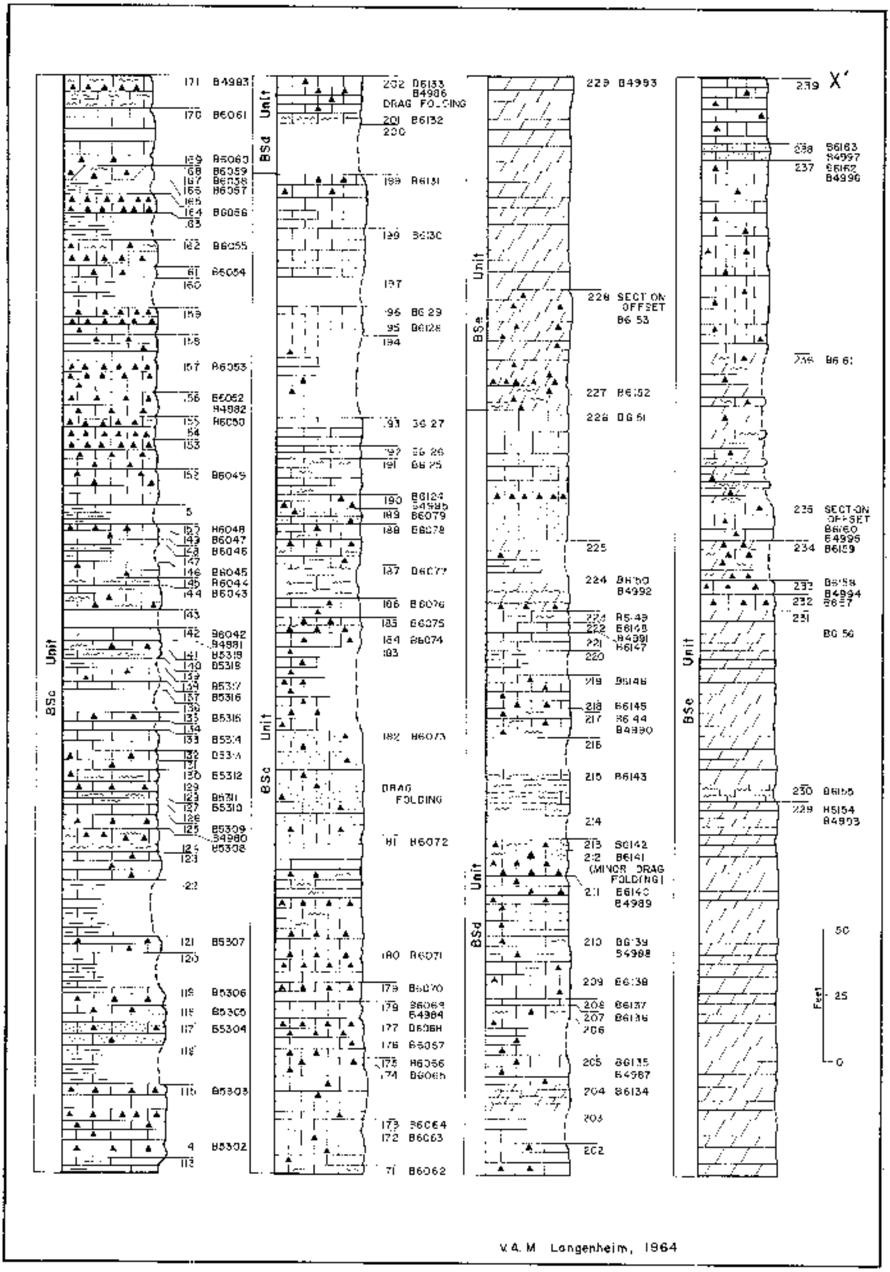

FIGURE 4.—Columnar section of the upper portion of the Bird Spring Group as exposed in Arrow Canyon.

Battleship Wash Formation. — The basal contact with the underlying Monte Cristo Group is well exposed at the type section in the north wall of Arrow Canyon at the lower entrance to the deep and narrow upper gorge. Here an interbedded sequence of cherty, sandy limestone and brown-weathering, calcareous sandstone rests on thick-bedded, fine-to medium-grained, gray limestone in the Monte Cristo Group. The sandstone, though discontinuous and inconspicuous, is a most useful feature in recognizing the contact and is the most important physical evidence of an interruption in deposition. Species of *Faberophyllum*, present in the lowermost sandy unit, also occur in the Brazer Group of northern Utah (Duley, 1957; Parks, 1951) and have been identified as Chesterian, whereas *Lithostrotionella* sp. and other fossils in the uppermost Yellowpine Limestone of the Monte Cristo Group are Meramecian or possibly Osagian. Thus the apparent hiatus at this contact amounts to all or part of Meramecian time and provides further evidence of a disconformity.

The basal sandstone member at the type section is a 4½ foot interval of interbedded sandy limestone and calcareous sandstone in beds approximately 4 inches to 1 foot thick. These rocks are slabby and weather readily to form a bench or reentrant that is easily overlooked in the field because of debris derived from rocks above and below. At Arrow Canyon, the basal member contains abundant specimens of *Faberophyllum* sp.

A middle member, approximately 65 feet thick at the type locality, consists of medium-grained, thick-bedded limestone characterized by blocky jointing and strikingly parallel bedding. These rocks weather dark olive-gray in contrast to the lighter gray rocks of the Monte Cristo Group. In addition, these rocks are spar cemented in contrast to the lime-mud cemented limestone below. Fossils are notably absent.

An uppermost member consists of about 8 feet of medium-grained limestone which weathers purplish-gray and is more thinly bedded than the middle member. Bedding plane surfaces bear an interesting association of *Stigmaria* sp., shark teeth, solitary rugose corals and spiriferid brachiopods.

BSB unit. — This unit consists of 243 feet of shaly rocks and characteristically forms a prominent strike valley or bench. Exposures are poor and all but three feet of the unit are covered on the line of the traverse. Scattered outcrops show that, although black and red shale is prominent in the covered sequence, argillaceous limestone and calcareous sandstone probably are as abundant. Bed 2, a characteristic limestone, is fine-grained, and weathers rusty. It has approximately 5% insoluble residue, chiefly fine sand and silt and contains the same brachiopod fauna as that occurring in the basal part of the BSc unit.

BSc unit. — Strata aggregating about 2200 feet in the Arrow Canyon section constitute this heterogeneous unit dominated by different kinds of limestone some of which are cherty. These rocks, together with shale and sandstone, occur in what is regarded to be a cyclical alternation.

Beds 5 through 8, 285 feet thick, are composed chiefly of fine-grained, gray limestone which weathers gray to rusty. Silicified fossils are locally abundant and the following brachiopods are especially prominent: *Schizophoria texana*, *Punctospirifer campestris*, *Spirifer occiduus*, and *Antiquatonia hermosana*. An insoluble residue as much as 27% is composed chiefly of fine sand and silt.

Beds 9 through 31, comprising about 210 feet, are relatively thick-bedded limestone. Limestones in this sequence range from fine- to coarse-grained; they are predominantly dark gray and weather light gray. Chert is sparse in the lower half of this unit but becomes relatively abundant stratigraphically upward. Fossils are more conspicuous in the upper half and include chiefly brachiopods, bryozoans and echinoderm fragments.

Beds 32 and 33, approximately 150 feet thick, are covered on the line of traverse and are drag folded. They are composed of more argillaceous limestone. Locally abundant brachiopods within this sequence include *Spirifer occiduus*, *Hustedia rotunda*, *Cleiothyridina orbicularis*, *Punctospirifer campestris*, *Linoproductus prattenianus*, *Antiquatonia hermosana*, and *Orthotetes* cf. *O. occidentalis*.

Beds 34 through 45, approximately 230 feet thick, are composed of cherty limestone ranging from fine- to coarse-grained and are chiefly dark gray to medium gray. The insoluble residue generally is less than 10%. Brachiopods, bryozoans and echinoderm fragments are abundant and rugose corals occur in beds 42 and 43.

Beds 46 to 54, approximately 125 feet thick, are characterized by insoluble residues ranging from 10% to 32%. These dark gray, fine-grained limestone beds weather gray to buff. Fossils are not prominent.

Beds 55 through 60, approximately 65 feet thick, consist of limestone grading upward into calcareous siltstone. The fine- to medium-grained, gray limestone is cherty and contains about 10% insoluble residue. Silicified brachiopods occur in bed 56. The gray calcareous siltstone weathers to gray and buff and contains chert nodules. It is composed of approximately 60% insoluble fine sand and silt.

Beds 61 through 89, about 175 feet thick, are composed of repeated sequences of relatively thin beds of chert and limestone, silty limestone, and calcareous siltstone. Insoluble content ranges to 53% but, within the limestone, is from 3 to 15%. Quartz fine sand and silt dominates the residues. These light to dark gray rocks weather gray or buff. Brachiopods, bryozoans, and echinoderm fragments are present.

Beds 90 to 91, approximately 43 feet thick, consist of medium- to coarse-grained limestone with insoluble residues of quartz fine sand and silt ranging from 20% to 45%.

Beds 92 through 98 are composed of about 65 feet of relatively chert-free, fine- to coarse-grained limestone. Insoluble residues are either less than 10% of sand and silt or are larger and composed of clay.

Beds 99 and 100 total 35 feet thick and are composed of coarse-grained, sandy limestone which is light gray and weathers buff to brown.

Beds 101 through 151, approximately 190 feet thick, are characteristically shaly and relatively chert-free. This easily eroded sequence is composed of thin units of fine- to medium-grained, gray to black, sandy or silty limestone alternating with poorly exposed, relatively thick units of thin-bedded shaly, nodular limestone. Insoluble residues, chiefly of fine sand and silt, range from 5% to 25%. *Chaeteles favosus* occurs in bed 112. Brachiopods, fenestellid bryozoans, solitary corals and fusulinids are locally abundant.

Beds 152 through 169, approximately 125 feet thick, are characterized by more abundant chert. Insoluble residues are generally less than 10% but range from 1.2% to 52%. Limestones range from fine- to medium-grained. Shaly limestone is confined to beds 160, 163 and 165 and bed 166 is dolomitic. Brachiopods and fenestellid bryozoans are the most prominent fossils, but *Caninia* sp. occurs in bed 156.

Beds 170 through 182 consist of about 190 feet of relatively thick-bedded, fine- to coarse-grained limestone. Chert is moderately abundant, but shaly or silty layers are absent. Insoluble residues range from a trace to from 20% to 30%. These cliff-forming rocks cause a narrows in the canyon. Bed 182 is notably drag-folded. Brachiopods and bryozoans are locally abundant and *Wedekindellina* (?) sp. occurs in beds 174 and 176.

Beds 183 through 199, about 200 feet of rock, are chiefly of thick-bedded, fine-grained limestone, but include several prominent interbedded layers of calcareous siltstone and silty limestone. Chert is largely confined to the lower half of this sequence. Insoluble residues of silt and fine sand range from a trace to about 25% in the limestone and 30% to 50% of the silty rock is carbonate. *Fusulina* (?) sp. occurs in bed 190 and brachiopods and bryozoans occur locally throughout the sequence.

BSd unit. — This unit includes beds 200 through 226 and is about 320 feet thick at Arrow Canyon. It is characterized by resistant thick-bedded, relatively pure limestone sequences alternating with nodular, shaly, cherty intervals which erode to form gullies and benches.

The limestone sequences range from 10 to 50 feet thick and generally are composed of layers ranging from a few inches to 2 feet thick. A few exceptional layers in bed 226 are as much as 8 feet thick. The limestone is chiefly fine-grained, but medium-grained limestone, with or without scattered coarse crystals, is present. Insoluble residues of fine sand or silt are characteristic and range from 5% to 20%. Beds 224 and 225 are dolomite. The silty sequences are as much as 20 feet thick, and, although largely covered, are characterized by layers from 6 inches to 1 foot thick of nodular aspect.

Fusulinids are abundant in the limestone beds. *Triticites* spp., including *T. californicus*, occur in beds 210, 212, and 223. *Schwagerina* sp. has also been noted in bed 223. Bryozoans, brachiopods, rugose corals, and *Syringopora* spp. are locally abundant.

BSe unit. — Approximately 530 feet of this unit were measured and described. The lower three-fifths is dolomite and forms the prominent cliffs capping outcrops of the BSd unit. These rocks are exposed where steeply dipping beds flatten abruptly to the east in Arrow Canyon. Beds 227 to 228 are composed of about 45 feet of fine-grained, gray dolomite which weathers buff. Layers are as much as 3 feet thick and contain scattered chert nodules. Insoluble residues of white silt range from 5% to 20%. Beds 229 to 231 comprise about 290 feet of similar, but chert-free, dolomite.

The upper two-fifths of the measured part of the unit, about 195 feet of rock in beds 232 through 239, consists of fine-grained, light gray limestone in layers as much as 3 feet thick. Minor dolomite layers are interbedded and scattered chert nodules are present. Scattered fossil occurrences include *Kleopatrina ftatateeta* and *Syringopora mccutcheonae* in bed 237; *Durhamina cordillerensis* in bed 233; and fusulinids in beds 232, 235, 236, and 238.

Age and Correlation.—Although relatively few fossils have been described and illustrated from Pennsylvanian and Permian rocks in the Great Basin, Bissell (1962a, b) and Brill (1963) have published zonal schemes for these rocks based on fusulinid occurrences. Coogan (1962, 1964) has outlined a somewhat more detailed subdivision of pre-Desmoinesian rocks in which he utilizes the ranges of fusulinids and other invertebrates and Wilson and Langenheim (1962) have recognized a set of coral zonules in the Wolfcampian and Leonardian. These schemes, along with the unpublished fusulinid zone classification of Welsh (1959), are arranged according to the standard stages and zones for Pennsylvanian and Permian rocks (Moore and Thompson, 1949; Thompson, 1948) in Figure 5.

Thirty-one fossil invertebrate species, determined in the course of this study, are tabulated in Figure 6 according to their stratigraphic occurrence. Some of these species can be related to one or another of the already described zones and, therefore, serve to correlate the Arrow Canyon rocks with rocks elsewhere in the Great Basin or with the standard North American Pennsylvanian and Permian biostratigraphic units. Ranges of other species are not well known, and it is hoped that determination of their range at Arrow Canyon may be useful for future stratigraphic work in the region.

Punctospirifer campestris, *Schizophoria texana*, *Cleiothyridina orbicularis* and *Antiquatonia hermosana*, occurring in beds 6, 29, and 33, along with other brachiopods and *Acanthopecten* sp., are all characteristic of the *Rhipidomella nevadensis* fauna of the Great Basin. N. G. Lane (1963) has described *Schizophoria texana*, *Orthotetes occidentalis*, and *Anthracospirifer birdspringensis* (*Spirifer occiduus* of this report) and assigns them to the late Morrowan. B. O. Lane (1962), however, reports *Spirifer occiduus*, *Punctospirifer campestris* and *Antiquatonia hermosana* occurring stratigraphically above *Fusulinella* and *Profusulinella* in the White Pine Range, thereby extending their ranges at least to the middle Atokan.

Coogan (1962, 1964) assigns the entire BSb unit and the basal 95 feet of the BSc unit at Arrow Canyon, which includes our bed 6, to his *Flexaria-Reticularina-Michelinia* Faunizone. The overlying *Millerella marblensis-Staffella expansa-Caninostrotion* sp. Faunizone (Coogan, 1962, 1964) apparently includes our beds 29 and 33 in the lower portion. According to Coogan (1962, 1964) *Antiquatonia hermosana*, *Schizophoria texana* and *Spirifer occiduus* range throughout the *Millerella marblensis* etc. Faunizone and *Reticularina campestris* (*Punctospirifer campestris* of this report) may occur in the lower portion.

Coogan (1962, 1964) places the *Flexaria* etc. Faunizone somewhere between the Late Chesterian and the Early Morrowan but declines to recognize Springeran rocks in the Great Basin. He places the *Millerella expansa* etc Faunizone in the Morrowan.

Welsh (1959), on the basis of his recognition of *Rhipidomella nevadensis*

ST'D. STAGES and ZONES		BISSELL, 1962 a b		BRILL, 1963	WELSH, 1959	(A) WILSON and LANGENHEIM, 1962 (B) COOGAN, 1962
GUADALUPIAN	*POLYDIEXODINA*	GUADALUPIAN				(A)
	PARAFUSULINA		*Leella fragilis*			
LEONARDIAN	*PARAFUSULINA*	LEONARDIAN	*Parafusulina (Parafusulina) bosei*			*Heritschiodes hillae* / *Orionastrea hudsoni*
			Parafusulina (Skinnerella) diablcensis	*Schwagerina hessensis, S. hawkinsi, S. guembeli, S. crassitectoria,* and *Pseudofusulina lativentra*		?
			Parafusulina (Skinnerella) schucherti			*Durhamina cordillerensis*
WOLFCAMPIAN	*PSEUDOSCHWAGERINA*	WOLFCAMPIAN	*Schwagerina youngquisti*	*Schwagerina wellesensis, Pseudoschwagerina gerontica, S. compacta,* and *Monodiexodina linearis*	*Pseudoschwagerina cf. P. convexa, P. cf. P. gerontica, S. cf. S. linearis, S. cf. S. diversiformis*	(Zone 2 of Easton, 1960)
			Schwagerina elkoensis	*Triticites californicus, T. cellamagnus, Schwagerina emaciata,* and *S. complexa*	*Schwagerina cf. S. neolata, S. cf. S. eolata, Pseudofusulina cf. P. moranensis*	? *Syringopora mccutcheonae -Thysanophyllum princeps* (Zone 1 of Easton, 1960)
			Triticites cellamagnus			? *Caninia hanseni*
VIRGILIAN	*TRITICITES*	VIRGILIAN	*Triticites cullomensis*	*Triticites cullomensis, T. hobblensis, T. plummeri*	Ventricose *Triticites* / *Dunbarinella*	
			Triticites kellyensis		*Waeringella*	
			Triticites plummeri			
MISSOURIAN	*TRITICITES*	MISSOURIAN	*Kansanella (Kansanella) grangerensis*	Primitive *Triticites spp.* such as *T. springvillensis* and *T. provoensis*	Cylindrical *Triticites*	
			Triticites provoensis			
			Triticites springvillensis		*Waeringella ultima*	
DESMOINESIAN	*FUSULINA*	DESMOINESIAN	*Fusulina megista*	*Fusulina spp.*	*Fusulina*	(B)
			Wedekindellina euthysepta	*Wedekindellina spp.*	Subzone of *Wedekindellina*	
ATOKAN	*FUSULINELLA*	DERRYAN	*Fusulinella acuminata*	*Profusulinella spp* and primitive spp. of *Fusulinella, Chaetetes sp*	*Fusulinella*	*F. devexa*
						F. acuminata - Komia sp. / *Multitheco pora sp.- Chaetetes sp.*
	PROFUSULINELLA		*Profusulinella apodacensis*		*Profusulinella*	*F. fugax - Chaetetes sp.*
						P. decora - Chaeteres
						P. copiosa - Caninia torquia
MORROWAN	*MILLERELLA*	MORROWAN	*Millerella marblensis*	*Millerella spp., Eoschubertella spp., Hustedia miseri*	*Millerella* and *Paramillerella*	*Millerella marblensis - Staffella expansa - Caninostrotion sp. A.*
SPRINGERAN	*MILLERELLA*	SPRINGERAN	*Paramillerella circuli*	*Rhipidomella nevadensis, Schizophoria texana, Chonetes sp.*	*Rhipidomella nevadensis*	Morrowan, Chesterian or neither / *Flexaria*
Chest.		Late Chest.	*Atetsuella meandra*			*Cravenoceras merriami - Mooreoceras sp.*

FIGURE 5.—Pennsylvanian and Permian biostratigraphic units employed in the Great Basin Province.

UNIT	BSc Unit													BSd Unit						BSe Unit			
FOSSILS / BED	6	29	33	42	56	101	112	125	142	171	174	176	190	205	210	211	212	217	223	229	233	237	238
FORAMINIFERA																							
Fusulina (?) sp.													X										
Schwagerina sp.																			X				
Triticites sp.															X								
Triticites californicus																			X				
T. cf. T. californicus																	X						
Wedekindellina sp.											X	X											
COELENTERATA																							
Caninia sp.						X																	
Chaetetes favosus							X																
Durhamina cordillerensis																					X		
Kleopatrina ftatateata																						X	
Pseudozaphrentoides ordinatus																		X					
Stereostylus nebulus								X															
Syringopora cf. S. catenoides														X									
S. mccutcheonae																						X	
S. (?) mozarti														X									
S. multattenuata														X				X					
S. cf. S. multattenuata																X				X			X
BRACHIOPODA																							
Antiquatonia hermosana	X	X	X																				
Cleiothyridina orbicularis			X																				
Composita subtilita								X															
Hustedia rotunda			X																				
Linoproductus prattenianus			X	X	X			X															
Meekella sp.	X																						
Neospirifer cameratus								X															
Orthotetes cf. O. occidentalis			X																				
Punctospirifer campestris	X		X																				
P. kentuckyensis										X													
Schizophoria texana	X																						
Spirifer occiduus	X		X		X			X						X									
Wellerella tetrahedra									X														
MOLLUSCA																							
Ancanthopecten sp.			X																				
SAMPLE NUMBERS	B4972; 5199	B4973; 5229	B4974	B5252	B4976; 5264	B4978; 5294	B4979	B4980; 5309	B4981; 6042	B4983; 6062	B6065	B6067	B4985; 6124	B4987; 6135	B4988; 6139	B4989; 6140	B6141	B4990; 6144	B6149	B4993; 6154	B4994; 6158	B4996; 6162	B4997; 6163

FIGURE 6.—Checklist of fossils from the Bird Spring Group at Arrow Canyon.

in the Arrow Canyon section assigns rocks apparently equivalent to our beds 5 through the basal ¼ of bed 8 to the *Rhipidomella nevadensis* zone. His correlation of these rocks is somewhat ambiguous, however, inasmuch as he assigns the collections to the Morrowan in his description and illustration of the columnar section (Welsh, 1959, p. A-105, Enclosure 12) but limits occurrences of *Rhipidomella nevadensis* to the zone of that name (Welsh, 1959, Table I, p. 26) which he tentatively refers to either the Springeran or Morrowan (Welsh, 1959, p. 25, 30). Our collections from bed 6 fall within this sequence but do not include *Rhipidomella nevadensis;* they do include abundant *Schizophoria texana,* however, a brachiopod which grossly resembles *R. nevadensis.*

Welsh (1959, p. 30) assigns all rocks between the highest occurrence of *R. nevadensis* and the lowest occurrance of *Profusulinella,* his station NAC-177 through NAC-187+(20-30), to the Zone of *Millerella* and *Paramillerella.* This sequence apparently includes our collections from beds 29, 33, 42 and 56.

Coogan (1962, 1964) defined the *Millerella marblensis-Staffella expansa-Caninostrotion* sp. Faunizone at Arrow Canyon and used his units 54 through 124, essentially equivalent to our beds 10 through 107, as the type section. Thus our collections from beds 29, 33, 42, 56 and 101 belong to this Faunizone as defined by Coogan. Coogan (1962) reports the following species from this zone which have also been collected here by us: *Antiquatonia hermosana, Hustedia* cf. *H. miseri* (*H. rotunda* of this report), *Linoproductus prattenianus, Spirifer occiduus,* and *Reticularina campestris* (*Punctospirifer campestris* of this report).

Welsh (1959) assigns rocks which apparently fall between our beds 101 and 112 to the Zone of *Profusulinella* and Coogan (1962, 1964) apparently recognizes the same zone in our beds 108 through 111. Thus we have no fossils representative of this zone in our collections.

Both Welsh (1959) and Coogan (1962, 1964) apparently assign rocks equivalent to our beds 112 through 144 to the Zone of *Fusulinella.* Our collection of *Chaetetes favosus* from bed 112 is apparently equivalent to Welsh's *Chaetetes* sp. biostrome at his station NAC-789+(10-20) and to the occurrence of *C. favosus* reported by Coogan (1962, 1964) in his unit 162. Coogan's unit 160 apparently also is included within our bed 112 and is assigned by Coogan to the *Chaetetes favosus-Multithecopora* n. sp. Faunizone and probably to the *Fusulinella fugax-Chaetetes favosus* Faunizone. We, however, have not collected any of the characteristic invertebrates, other than *C. favosus,* reported by Coogan from these rocks.

Our collections from beds 125 and 142 are within the Zone of *Fusulinella* as reported by both Coogan (1962) and Welsh (1959) and both collections appear to fall within the *Fusulinella acuminata-Komia* Faunizone of Coogan. None of the brachiopods or the coral collected by us, however, are reported by Coogan (1962). Welsh's (1959) report of *Composita* sp., *Lophophyllidium* sp., *Neospirifer* sp., *Punctospirifer* sp. and *Spirifer opimus* probably is equivalent to our *Composita subtilita, Sterostylus* n. sp., *Neospirifer cameratus, Punctospirifer kentuckyensis* and *Spirifer opimus.*

Welsh (1959) reports *Wedekindellina* sp. from many beds in an interval apparently equivalent to our beds 135 through 188, and, on this basis, assigns these rocks to the Subzone of *Wedekindellina.* Our two collections of *Wedekindellina* sp. from beds 174 and 176, as well as a collection of *Punctospirifer kentuckyensis* from bed 171 also are from this interval.

Welsh (1959) assigns rocks roughly equivalent to our beds 188 through 195 to the Zone of *Fusulina,* and these rocks, at bed 190, yielded our collection of *Fusulina* (?) sp.

Welsh (1959), on the basis of single occurrences of *Waeringella (Wedekindellina) ultima* and *Triticites* (?) sp., places rocks roughly equivalent to our beds 199 through 210 in the Missourian. Our collection of *Triticites* sp. from bed 210 supports Welsh's conclusion, but our only other Missourian collection, four species of *Syringopora* from bed 205, has little stratigraphic significance.

Welsh's (1959) Zone of ventricose *Triticites* includes rocks ranging from his station NAC-796+20 through NAC-800 and is subdivided into a lower *Waeringella* subzone and an upper *Dunbarinella* subzone. This sequence appears to includes beds 211 through 226, but our collections of Permian fusulinids. *Triticites* cf. *T. californicus* from bed 212 and *T. californicus* and *Schwagerina* sp. from bed 223, contradict Welsh's correlation of these rocks with the Virgilian. Brill (1963), p. 321, fig. 14) also shows *Triticites californicus* at the base of the Permian and about 50 feet below the base of a prominent dolomite sequence. Therefore the occurrence is probably from our bed 223, which is approximately 75 feet below the base of the thick dolomitic sequence and which has yielded *Schwagerina* sp. and *T. californicus*. Welsh's collection of *Triticites* sp. from a bed ten feet below the base of the dolomite is probably unrelated to our collections or those of Brill (1963).

We have also collected *Syringopora* cf. *S. multattenuata* (beds 211 and 217) and *Pseudozaphrentoides ordinatus* (bed 217) from Virgilian rocks at Arrow Canyon. Ross and Ross (1962) originally described *P. ordinatus* from Virgilian rocks near the top of the Gaptank Formation in the Glass Mountains, Texas. Welsh's (1959) reports of *Pseudozaphrentoides* (?) from his Missourian collections NAC-795 and NAC-796 and his Virgilian collection NAC-798+(40-50) may or may not be taxonomically equivalent to our *P. ordinatus*.

Welsh (1959) describes 810 feet of Wolfcampian Apex Formation, placing the base at the bottom of a prominent, thick-bedded, cliff-forming dolomite sequence. We have measured and described only 530 feet of Wolfcampian rock which includes Welsh's Apex Formation through his station NAC-187 + 90. Welsh (1959) reports many occurrences of *Schwageriana* sp. and *Pseudoschwagerina* sp. within this sequence and we have also collected many fusulinids from these rocks. We, however, have found them difficult to identify because of silicification.

Association of *Kleopatrina ftatateeta* and *Syringopora mccutcheonae* in bed 237 (McCutcheon and Wilson, 1961; Wilson and Langenheim, 1962) is similar to an occurrence in Wolfcampian rocks of the Ely Quadrangle, 200 miles north of Arrow Canyon. In the Ely Quadrangle, however, these corals occur stratigraphically below *Durhamina cordillerensis*, which at Arrow Canyon, occurs in bed 233, below *K. ftatateeta*. This relationship is the reverse of that reported by Wilson and Langenheim (1962, p. 502) and used by them in establishing a sequence of coral zonules in the Ely Quadrangle. Except for the fact that minor morphologic differences between *D. cordillerensis* from Arrow Canyon and from the Ely Quadrangle may prove taxonomically significant, this invalidates the zonules of Wilson and Langenheim (1962) for use throughout the Great Basin. It is possible, however, that the absence of *D. cordillerensis* below *K. ftatateeta* at Ely is consequent upon the fact that there are no Permian rocks of suitable facies below the *K. ftatateeta* occurrance.

Syringopora multattenuata is present in beds 227 and 233, thus significantly extending both the stratigraphic and geographic range of this species (McCutcheon, 1961).

Summary

Approximately 3500 feet of Chesterian through Wolfcampian rocks assigned to the Bird Spring Group are well exposed in Arrow Canyon in the northeastern corner of the Arrow Canyon Quadrangle. These rocks are among the southeasternmost exposures of miogeosynclinal Late Mississippian through Permian rocks in this area, and the exceptional exposure at this locality is well fitted to serve as a regional standard of reference for future study.

Repetitive depositional patterns and subtle, complex facies relationships have frustrated attempts at region-wide classification of formational units and already described "rock" units are, in large part, defined by incompletely known biostratigraphic data. For this reason, we formerly employed a local classification of informal units in which the Bird Spring Formation was treated as a group divided into five units of formational rank: BSa, BSb, BSc, BSd, and BSe (Langenheim et al., 1962). We are now satisfied that the BSa unit has regional significance as a lithologically defined unit and, for this reason, have recognized it as the Battleship Wash Formation.

The Battleship Wash Formation is approximately 80 feet thick at Arrow Canyon. It is characterized by thick-bedded limestone and rests disconformably on the Yellowpine Limestone of the Monte Cristo Group. It is Chesterian.

The BSb unit is approximately 240 feet thick at Arrow Canyon and is characterized by readily eroded shale and sandy limestone. It is probably Springeran.

The BSc unit is approximately 2200 feet thick. It is composed of strikingly layered limestone and cherty limestone which is characteristic of the Bird Spring Group throughout its extent. It ranges in age from Springeran (?) through Missourian.

The BSd unit is approximately 320 feet thick and is composed of alternating sequences of resistant, cliff-forming limestone and readily eroded shaly limestone. It includes late Missourian, Virgilian and early Wolfcampian rocks, thus spanning the Pennsylvanian-Permian boundary. There is no convincing physical or biostratigraphic evidence of an unconformity.

The BSe unit is approximately 530 feet thick in our incomplete measured section. The lower part consists of thick-bedded dolomite and all of the measured and described portion of the unit is Wolfcampian.

ACKNOWLEDGMENTS

The senior author is currently associated with the Illinois State Geological Survey.

LITERATURE CITED

BISSELL, H. J. 1962a. Fusulinid range zones in Cordilleran Area (Abstract). Geol. Soc. Am. Special Paper 68: 7-8.

————. 1962b. Pennsylvanian and Permian rocks of Cordilleran Area *in* Pennsylvanian System in the United States. p. 188-263, Am. Assoc. Petrol. Geol., Tulsa, Oklahoma.

————. 1962c. Permian rocks of parts of Nevada, Utah, and Idaho. Geol. Soc. Am. Bull. (9): 1083-1110, 2 figs., 6 pls.

BOWYER, B., E. G. PAMPEYAN, and C. R. LONGWELL. 1958. Geologic map of Clark County, Nevada. U. S. Geol. Survey Min. Inv. Field Studies, Map MF 138.

BRILL, K. G. 1963. Permo-Pennsylvanian stratigraphy of western Colorado Plateau and eastern Great Basin Regions. Geol. Soc. Am. Bull. (3): 307-330, 17 figs., 1 pl.

COOGAN, A. H. 1962. Early Pennsylvanian stratigraphy, biostratigraphy, and sedimentation of the Ely Basin, Nevada. Unpub. Ph. D. Thesis, Dept. of Geology, Univ. Ill., Urbana, 90 p., 2 pls.

————. 1964. Early Pennsylvanian history of Ely Basin, Nevada. Am. Assoc. Petrol. Geol. Bull. (4): 487-495, 6 figs.

DUTLEY, D. H. 1957. Mississippian stratigraphy of the Meadow Valley and Arrow Canyon Ranges, Southeastern Nevada. Unpub. M. A. Thesis, Dept. Paleontology, Univ. Calif., Berkeley, 103 p., 7 figs., 3 pls.

EASTON, W. H. 1960. Permian corals from Nevada and California. J. Paleont., 34 (3): 570-583, 18 figs.

GLOCK, W. S. 1929. Geology of the east-central part of the Spring Mountain Range, Nevada. Am. J. Sci., 217: 326-341, 3 figs.

HEWITT, D. F. 1931. Geology and ore deposits of the Goodsprings Quadrangle, Nevada. U. S. Geol. Survey Prof. Paper 162, 172 p., 40 pls., 55 figs.

LANE, B. O. 1962. The fauna of the Ely Group in the Illipah Area of Nevada. J. Paleont., 36 (5): 888-911, 8 figs., pls. 125-128.

LANE, N. G. 1963. A silicified Morrowan brachiopod faunule from the Bird Spring Formation, southern Nevada. J. Paleont., 37(2): 379-392, 6 figs., pls. 43-45.

LANGENHEIM, R. L., JR. 1956. Lower Mississippian stratigraphic units in southern Nevada (Abstract). Geol. Soc. Am. Bull. 67 (12) pt. 2: 1773.

————————, et al. 1962. Paleozoic section in Arrow Canyon Range, Clark County, Nevada. Am. Assoc. Petrol. Geol. Bull. 46 (5): 592-609, 5 figs.

LANGENHEIM, V. A. M. 1964. Pennsylvanian and Permian paleontology and stratigraphy of Arrow Canyon, Arrow Canyon Range, Clark County, Nevada. Unpub. M. A. Thesis, Dept., Paleontology, Univ. Calif., Berkeley, 194 p., 10 figs., 6 pls.

LONGWELL, C. R. 1921. Geology of the Muddy Mountains, Nevada, with a section to the Grand Wash Cliffs in western Arizona. Am. J. Sci. 201: 39-62, 5 figs.

————————. 1928. Geology of the Muddy Mountains, Nevada. U. S. Geol. Survey Bull. 798, 152 p., 17 pls., 9 figs.

————————. 1949. Structure of the northern Muddy Mountain Area, Nevada. Geol. Soc. Am. Bull. 60 (5): 923-967, 14 figs., 11 pls.

————————, and C. O. DUNBAR. 1936. Problems of Pennsylvanian-Permian boundary in southern Nevada. Am. Assoc. Petrol. Geol. Bull. 20 (9): 1198-1207, 6 figs.

MALOTT, C. A., and J. D. THOMPSON, JR. 1920. The stratigraphy of the Chester series of southern Indiana (Abstract). Sci. ns 51: 521-522.

McCUTCHEON, V. A. 1961. Redescription of *Syringopora multattenuata* McChesney. J. Paleont., 35 (5): 1014-1016, pl. 12.

————————, and E. C. WILSON. 1961. *Ptolemaia*, a new colonial rugose coral from the Lower Permian of eastern Nevada and western Russia. J. Paleont., 35 (5): 1020-1028, 3 figs., pl. 123.

McNAIR, A. H. 1951. Paleozoic stratigraphy of part of northwestern Arizona. Am. Assoc. Petrol. Geol. Bull. 35 (3): 503-541, 2 figs.

MOORE, R. C., and M. L. THOMPSON. 1949. Main divisions of Pennsylvanian Period and Systems. Am. Assoc. Petrol. Geol. Bull. 33 (3): 275-302.

PARKS, J. M. 1951. Corals from the Brazer Formation (Mississippian) of northern Utah. J. Paleont., 25: 171-186, pls. 29-33, 3 figs.

ROSS, C. A., and J. R. P. ROSS. 1962. Pennsylvanian, Permian rugose corals, Glass Mountains, Texas. J. Paleont., 36 (6): 1163-1188, 11 figs., pls. 160-163.

SPURR, J. E. 1903. Descriptive geology of Nevada South of the fortieth parallel and adjacent portions of California. U. S. Geol. Survey Bull. 208, 229 p.

SWARTZ, C. K. 1923. Geologic relations and geographic distribution of the Silurian strata of Maryland; Stratigraphic and paleontologic relations of the Silurian strata of Maryland. Maryland Geol. Survey, Silurian: 19-23, 25-51, 4 pls.

THOMPSON, M. L. 1948. Studies of American fusulinids. Univ. Kans. Paleontological Contrib., Protozoa, Art. 1, p. 1-184, pls. 1-38, 8 figs.

WELSH, J. E. 1959. Biostratigraphy of the Pennsylvanian and Permian Systems in Southern Nevada. Unpub. Ph. D. Thesis, Dept. Geol., Univ. Utah, 106 p., 13 figs., 8 tables, 22 encl., appendix p. A-1 A-215.

WILSON, E. C., and R. L. LANGENHEIM, JR. 1962. Rugose and tabulate corals from Permian rocks in the Ely Quadrangle, White Pine County, Nevada. J. Paleont., 36 (3): 495-520, 4 figs., pls. 86-89.

————————, R. H. WAINES, and A. H. COOGAN. 1963. A new species of *Komia* Korde and the systematic position of the genus. Palaeontology 6 (2): 246-253, 3 figs., pls. 34-35.

Manuscript received January 29, 1965.