

THE PILOT SHALE, THE WEST RANGE LIMESTONE, AND THE DEVONIAN-MISSISSIPPIAN BOUNDARY IN EASTERN NEVADA

R. L. LANGENHEIM, JR.
University of Illinois, Urbana

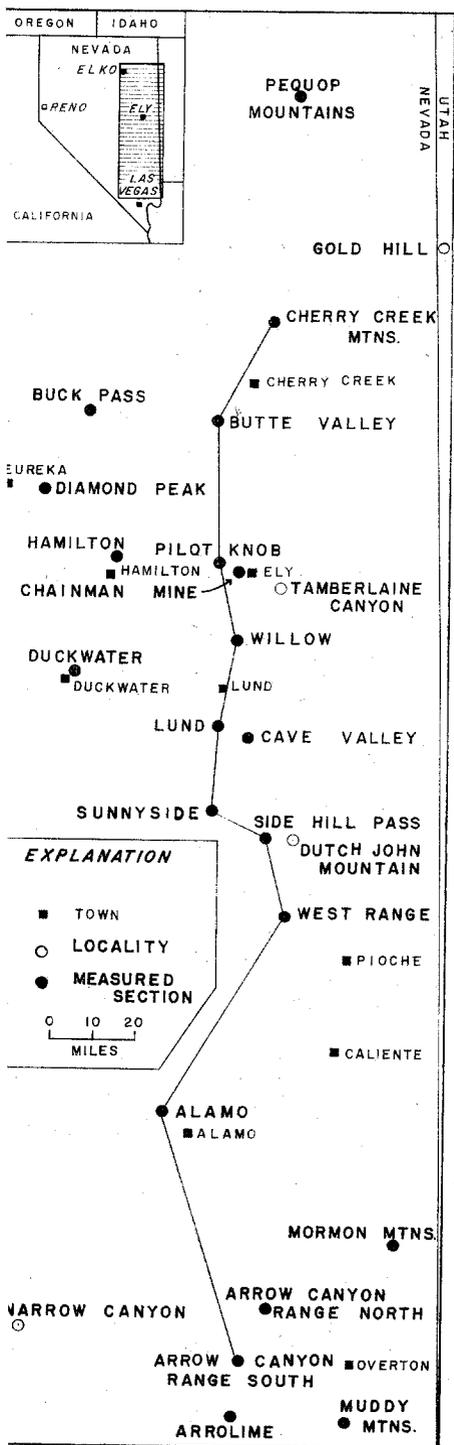
INTRODUCTION

The boundary between the Mississippian and Devonian systems and the age of the Pilot Shale have concerned stratigraphers in the Great Basin since Hague's first descriptions of the pertinent rocks in the White Pine and Eureka Mining Districts (1870, 1883, 1892). Spencer (1917) and Westgate (Westgate and Knopf, 1932) later named but only briefly described the Pilot Shale and the West Range Limestone. Furthermore, there are few other published descriptions of the generally poorly exposed rocks between the basal Mississippian Joana Limestone and the cliff-forming Upper Devonian rocks of Eastern Nevada. As a result many writers have classified all of the heterogeneous rocks near the Devonian boundary under the name "Pilot Shale". Thus, it appears desirable to present detailed descriptions of well-exposed sections of these rocks in order to prepare a foundation for further, more discriminating study (Fig. 1).

PREVIOUS WORK

Rocks at the Devonian-Mississippian boundary in Nevada were described early by Hague (1870) as calcareous shales of Devonian age in the White Pine (Hamilton) Mining District (Fig. 2). Later (1883, 1892) he included rocks now considered equivalent to the Devonian shale of the White Pine District in the White Pine Shale as he described it at

Eureka. Hague (1882, 1883), however, designated the White Pine Mining District as the source of the name for White Pine Shale. He considered the White Pine Shale Devonian, but, unfortunately, correlated rocks now recognized as Pilot Shale, Joana Limestone, and Chainman Shale at Eureka (Nolan, Merriam and Williams, 1956) with the type section of the White Pine Shale at Hamilton. The type section of the White Pine Shale, however, includes only those rocks equivalent to the Chainman shale of current U.S. Geological Survey usage. Lawson (1906) recognized a lower shale, a middle limestone, and an upper shale in the Robinson (Ely) Mining District which he correlated with Hague's sections at Eureka and Hamilton. Thus, Lawson repeated Hague's error in correlating between Eureka and Hamilton. Spencer (1917) later named the units recognized by Lawson as the Pilot Shale, the Joana Limestone, and the Chainman shale in ascending order. At this time all three formations were referred to the Carboniferous. In 1932 Westgate (Westgate and Knopf, 1932) described the West Range Limestone in the Pioche District and at Dutch John Mountain. As described, the West Range Limestone contains Late Devonian fossils and forms a bench-like outcrop above the Devonian Silverhorn Dolomite and below the Mississippian Bristol Pass (Joana) Limestone. Merriam (1940) later



noted approximately 300 feet of dark argillaceous to shaly limestone ("Zone D") and 85 feet of thin bedded, platy, gray shale ("Zone E") immediately beneath the Mississippian limestone cliff at Dutch John Mountain. Merriam considered these rocks either Devonian or Mississippian, and, on the basis of faunal evidence, placed the base of the shaly sequence 750 feet above the "West Range limestone". In the National Research Council correlation chart of 1942 (Cooper *et al.*, 1942), zone D is referred to the West Range Limestone, and neither zone E nor the Pilot Shale is mentioned. In the comparable Mississippian chart (Weller *et al.*, 1948) the West Range Limestone is referred to the Devonian and the Pilot Shale to the Mississippian. A more recent correlation chart prepared by the Eastern Nevada Geological Association (1953) considers the Pilot Shale as Devonian or Mississippian and definitely refers the West Range Limestone to the Devonian. Nolan, Merriam, and Williams (1956, pp. 52-53) describe a lower calcareous shale with Late Devonian conodonts and an upper platy black, unfossiliferous shale at Eureka as the Pilot Shale. The upper shale is considered Devonian or Mississippian. Reso and Croneis (1959), however, assign 400 feet of Pilot shale resting on 410 feet of West Range Limestone to the Devonian System in the Pahranaagat Range. To the southwest in the A.E.C. Proving Ground, Johnson and Hibbard (1957) describe the Narrow Canyon Limestone, consisting of 175

Fig. 1.—Location Map. Line connects locations of measured sections shown in Figure 3.

feet of Late Devonian or Early Mississippian platy, dark gray, buff-weathering silty limestone, that is tentatively correlated with the Pilot Shale, as described by Spencer (1917).

This confusing tangle largely results from a series of detailed local studies of sections in widely spaced areas. Quite properly, the earlier investigators defined local rock units to provide structural datum planes and a stratigraphic framework for their fossil collections. Thus, these rocks are yet to be classified according to their regional extent and significance—an essential part of any investigation of the geologic history of a large area.

ACKNOWLEDGMENTS

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REFERENCE SECTIONS

The Pilot Shale is described by Spencer (1917) as a poorly exposed, nonfossiliferous, soft, black to drab, highly carbonaceous shale 100 to 400 feet thick. Examination in 1955 of the area mapped by Spencer adds little to this information, and the name-giving locality, Pilot Knob, is now covered by waste rock from the Veteran copper pit. The best-exposed nearby section, approximately one mile north of Pilot Knob, shows only a covered slope between the Joana Limestone and an argillaceous buff-weathering, gray limestone containing the *Cyrtospirifer* fauna (Fig. 3). Therefore, an exposure south-southwest of the triangulation station "Willow" on the west flank of the Egan Range and approximately two miles north of the south boundary of the Ely No. 3 Quadrangle has been selected as a reference section for the Pilot Shale (Fig. 3).

At the Willow section, the Upper Pilot Shale consists of 190 feet of nonfossiliferous black, fissile shale. This rock is cleanly exposed and appears to contain little silty or calcareous rock. The upper contact with the Joana Limestone is sharp, as is the basal contact with fossiliferous, calcareous siltstone. The lower 193.1 feet of the Pilot Shale is dominated by black, calcareous siltstone with interbedded silty limestone and minor amounts of fine-grained gray limestone. The basal contact is

sharp, but limestone interbedded in the basal portion of the Lower Pilot Shale resembles the limestone of the Guilmette Limestone below. The silty limestone and fine-grained limestone weather buff and are the probable source of the weathered rock chips covering most Pilot Shale outcrops. The lower Pilot Shale contains abundant fossils including *Nudirostra* sp. of Devonian aspect. A detailed description of the Willow reference section follows:

The 383.1 feet of Pilot Shale at Willow are comparable to the 350 feet of covered rock assigned to the Pilot Shale just north of Pilot Knob (Fig. 2). Thus, it is assumed that the members at Willow are also present at Pilot Knob and underlie the bench between the Joana Limestone and Guilmette Limestone on the west side of Ward Mountain as mapped by Langenheim *et al.* (1959).

Westgate (Westgate and Knopf, 1932, p. 16) describes the West

UNIT	THICKNESS	DESCRIPTION
Joana Limestone		Limestone, fine to medium-grained; gray, weathering light gray; beds more than 5 feet thick.
Disconformity		
Upper Pilot Shale		
13	190.0	Shale; black, weathering buff; fissile to platy; homogeneous clay shale with little silty material.
Lower Pilot Shale		
12	2.7	Silty limestone or calcareous siltstone; black, weathering buff; single massive layer; <i>Nudirostra</i> sp.
11	21.0	Scattered outcrops calcareous siltstone or silty limestone; black, weathering buff to pink; platy talus.
10	17.0	Limestone, fine-grained; black, weathering buff to gray; beds as much as 1 foot thick separated by calcareous siltstone or silty limestone; fossiliferous.
9	8.5	Calcareous siltstone or silty limestone; black, weathering buff to pink-buff; beds as much as 2 inches thick weathering to plates $\frac{1}{4}$ inch thick.
8	9.0	Covered.
7	30.0	Scattered outcrops of limestone, very fine-grained; gray, weathering gray to buff-pink in mottled pattern separated by areas of buff soil with chips of silty limestone.
6	3.4	Limestone, fine-grained; black, weathering gray; beds as much as 3 feet thick.
5	7.5	Covered.
4	6.0	Limestone, fine-grained; black, weathering gray; beds as much as three feet thick.
3	44.0	Scattered outcrops and talus of silty limestone or calcareous siltstone; gray, weathering buff to buff-pink; platy.
2	22.0	Limestone, fine-grained; dark gray, weathering gray; beds as much as 1 foot thick separated by units of similar thickness of limestone, fine-grained; dark gray, weathering gray to buff; platy.
1	22.0	Covered.
Guilmette Limestone		Limestone, fine-grained; black, weathering mottled gray; beds 1 foot thick.
Total Thickness, Upper Pilot Shale—190.0 feet.		
Total Thickness, Lower Pilot Shale—193.1 feet.		

Range Limestone as "Blue gray, fine-grained limestone, in some places nodular, commonly weathering to a characteristic yellow color" between a prominent quartzite at the top of the Silverhorn Dolomite and the base of the Bristol Pass (Joana) Limestone. According to Westgate the West Range Limestone ranges in thickness from 330 feet at Dutch John Mountain to 615 feet at the type locality in the West Range and contains abundant Late Devonian fossils of the "*Spirifer whitneyi*" fauna. Inasmuch as the West Range Limestone occupies a stratigraphic position similar to that of the Pilot Shale, has a similar topographic expression, and also is deeply covered by buff-weathered debris, there has been some confusion regarding the distinct character of the two units.

Figure 2 shows a composite of two sections measured at opposite ends of the limited exposure on the conical hill just north of township 2 in the West Range. This is the area designated as the type locality of the West Range Limestone by Westgate (Westgate and Knopf, 1932).

Thicknesses as measured are 328 feet at the south end of the outcrop, where the top and bottom of the formation are well exposed, and 350 feet at the northern end of the outcrop, where the uppermost 100 feet of the formation and the contact are covered by talus. Fine-grained, gray limestone in beds one inch to two feet thick dominates. Thinner beds are more argillaceous, tend to be nodular, and contain most of the fossils. Thirty-two feet of platy calcareous siltstone crops out at the top of the southern section. This rock resembles the most abundant rock in the Lower Pilot Shale at Willow and is tentatively assigned to the Lower Pilot Shale. Crinoidal limestone of the Bristol Pass (Joana) Limestone rests on the calcareous siltstone in a sharp contact. The basal contact of the West Range Limestone is a well-marked sharp contact with the upper quartzite member of the Silverhorn Dolomite.

A detailed description of the type section of the West Range Limestone is as follows:

UNIT	THICKNESS	DESCRIPTION
Bristol Pass Limestone (Joana Limestone)		
7		Limestone, fine to medium-grained; gray, weathering light gray; beds more than 20 feet thick.
6	21.0	Limestone, medium-grained; gray, weathering light gray; beds approximately 4 inches thick; <i>Spirifer centronatus</i> (?).
Disconformity		
Lower Pilot Shale		
5	32.0	Calcareous siltstone or silty limestone; dark brown to buff or pink buff on weathered surfaces; platy.
West Range Limestone		
4	50.0	Limestone, fine-grained; gray, weathering buff; beds as much as 2 inches thick in lower half, 1 to 2 feet thick in upper half; unit becomes more silty toward top; abundantly fossiliferous.
3	146.0	Limestone, fine to very fine-grained; gray, weathering light gray with pink to buff partings; beds from 1 inch to 2 feet thick with thicker beds at intervals of from 5 to 7 feet; thin-bedded material nodular and more argillaceous; fossiliferous.

Silverhorn Dolomite		
2	3.8	Quartzite, fine-grained; pink-white, weathering white to rusty; bedding not apparent.
1		Dolomite, fine-grained; black, weathering black; bedding not apparent, laminated; <i>Cladopora</i> and scattered tetracorals.
Total Thickness, Lower Pilot Shale—32.0 feet.		
Total Thickness, West Range Limestone—296.0 feet.		

REGIONAL DEVELOPMENT OF STRATIGRAPHIC UNITS

Throughout the area several thousand feet of cliff-forming carbonate rocks make up the bulk of the Devonian system. Many different kinds of limestone and dolomite, as well as subordinant quartzite and shale, are included in this complex and largely unstudied sequence. This investigation is concerned, however, with only the uppermost portion of these rocks where they are in contact with the shaly and silty rocks of the Devonian-Mississippian transition.

In southern Nevada at the Mormon Mountain, Arrow Canyon Range, Arrolime, and Muddy Mountains sections, the Crystal Pass Limestone is the uppermost Devonian formation. This unit, originally described by Hewett (1931) at Goodsprings, is a very fine-grained, light gray limestone in beds two to four feet thick, which weathers to form a strikingly uniform white band of outcrop between black Mississippian limestone above and layered black and light gray Devonian limestone and dolomite below. Although no fossils have been described from the Crystal Pass Limestone, its gradational contact with the Devonian rocks below and its sharp, apparently disconformable contact with the Mississippian Monte Cristo Limestone above have led to a Late Devonian age assignment.

To the north at Alamo the uppermost part of the Devonian cliff-forming sequence consists of interbedded black dolomite, gray limestone, and rusty weathering quartzite. These rocks differ from the rocks below the Crystal Pass Limestone only in the higher proportion of sandstone in the upper portion, and have been assigned to the Guilmette Limestone by Reso and Croneis (1959). They fit well the original description of the Guilmette Limestone at Gold Hill (Nolan, 1935, pp. 20-21) but contrast sharply with the thick, light gray limestone sequence generally referred to the Guilmette Limestone by petroleum geologists working in eastern Nevada.

At Alamo the Guilmette Limestone is succeeded by 327.4 feet of less resistant limestone assigned to the West Range Limestone. The base of this formation is defined by the top of the highest dolomite bed of the Guilmette Limestone although similar limestone is present in the Guilmette Limestone. Fine-grained, light gray limestone, weathering light gray, occurring in beds as much as two feet thick, is most abundant, but shaly gray limestone, weathering buff, and in nodular layers three inches to one foot thick is also prominent. The formation is fossiliferous and contains elements of the *Cyrtospirifer* fauna as broadly defined. These rocks have been assigned to the West Range Limestone because of composition, weath-

ering character, and position in sequence. They are tentatively considered a more shaly facies equivalent of the Crystal Pass Limestone of the Arrow Canyon mountains.

The West Range Limestone of the type section rests directly on the uppermost quartzite member of the Silverhorn Dolomite (Westgate and Knopf, 1932). Farther north, however, at Side Hill Pass and at Sunnyside, 52 feet and 120 feet respectively of limestone intervene between the uppermost dolomite layer in the Guilmette Limestone and the West Range Limestone. The West Range Limestone is 352.1 feet thick at Side Hill Pass and 137.1 feet thick at Sunnyside. The formation is markedly more silty than at West Range, and detrital material is most prominent at Side Hill Pass where the *Cyrtospirifer* fauna as broadly defined is well represented.

At Lund 179.1 feet of fine-grained, light gray limestone assigned to the Guilmette Limestone is separated from the Joana Limestone by 15 feet of shaly limestone. At the base of this sequence a few intercalated beds of dolomite rest in turn on a much thicker sequence of limestone. Therefore, the West Range Limestone is shown in Figure 3 as terminating south of Lund, where it is replaced by the Guilmette Limestone facies. Alternatively, however, the West Range Limestone may have been eroded at the Lund section and may be present north of Lund in facies relationship with the Guilmette Limestone; it may be represented by one of the shaly sequences within 2518 feet of Guilmette Limestone at Ward Mountain (Willow); or it may be a facies of the Lower

Pilot Shale. Further investigation is suggested.

At Willow, Pilot Knob and Butte Valley fine-grained gray limestone in beds as much as four feet thick characterizes the Guilmette Limestone which is here succeeded directly by calcareous siltstone and limestone in the Lower Pilot Shale. At the Cherry Creek Mountains section, however, the uppermost Guilmette Limestone is more silty and argillaceous, forming three units as described below:

Uppermost Unit—408 feet, chiefly fine-grained, gray limestone in beds 2 to 4 inches thick, nodular and with shaly partings.

Middle Unit—336.5 feet, chiefly calcareous siltstone, dark gray, weathering buff, platy; interbedded with minor amounts of limestone as above; includes 19 feet of sandstone 65 feet above the base.

Lower Unit—328 feet, calcareous siltstone and limestone as described above, in alternating sub-units as much as 70 feet thick.

Although the relationship between the Guilmette Limestone, Sultan Formation, Crystal Pass Limestone, and West Range Limestone is poorly understood, a few generalizations are justified. Sandstone is more abundant, at the northern and southern extremities of the study area, with the Alamo and Arrow Canyon Range sections (lower part not shown in Figure 2) characterized by markedly more abundant and thicker sandstone beds. Argillaceous limestone, separately classified in the West Range Limestone, is widespread in the southern half of the area at the top of the Guilmette Limestone but does not occur in the extreme south. Argillaceous limestone and silty limestone are also

prominent to the north at the Cherry Creek and Pequop Mountains sections, but here the argillaceous rocks occur throughout the Guilmette Limestone. In contrast, the Guilmette Limestone of the Butte Valley-Lund area is characterized by predominance of fine-grained, relatively pure, gray limestone.

Rocks assigned to the Pilot Shale occur in the Eureka-Ely area, around Side Hill Pass, and at Alamo. Further north in the Cherry Creek and Pequop Mountains sections, the Joana Limestone rests directly on the Guilmette Limestone, and Nolan (1935, p. 21) reports a similar relationship at Gold Hill, Utah. The Pilot Shale is also absent at Duckwater and Cave Valley. Only 15 feet of buff-weathering gray, non-calcareous shale tentatively is assigned to this formation in the Lund section. Similarly, 32 feet of buff-weathering, calcareous siltstone is referred to the Lower Pilot Shale at the West Range section. The Pilot Shale and its presumed equivalent, the Narrow Canyon Limestone (Johnson and Hibbard, 1957, p. 356), are represented by thick sections at Alamo and Narrow Canyon respectively, but to the southeast the Monte Cristo Limestone rests directly on the Crystal Pass Limestone or older formations.

The section at Willow is the only well-exposed Pilot Shale section studied in the Eureka-Ely area, but the members exposed here appear widespread. Nolan, Merriam, and Williams (1956, p. 52) describe a similar subdivision of the Pilot Shale at Eureka. Furthermore, partial exposures of the basal silty member occur at Buck Pass, Hamilton, and

Chainman Mine; the upper black fissile shale member crops out at Buck Pass, Tamburlaine Canyon, and the Chainman Mine. At these localities the basal member consists chiefly of black to dark brown calcareous siltstone that weathers buff. Interbedded limestone also occurs at most localities and is either thin-bedded, shaly nodular dark gray limestone which weathers buff or is fine-grained, gray limestone occurring in beds as much as 2 feet thick which weather gray. Siltstone and limestone occur in both the Guilmette Limestone and Lower Pilot Shale and, in this area, the two formations are distinguished chiefly by the predominance of siltstone in the Lower Pilot Shale. The Lower Pilot Shale also includes fossils of the *Cyrtospirifer* Zone (Merriam 1940, p. 61) as broadly interpreted.

Only the Lower Pilot Shale is recognized in the Sunnyside-Side Hill Pass-West Range Area, where a maximum of 141.2 feet was measured at Side Hill Pass. In this section the lower 64 feet consists of interbedded black fissile shale, calcareous siltstone, and limestone, and the remaining 77.2 feet is chiefly shale and limestone with minor amounts of siltstone. To the east at Dutch John Mountain, however, a thicker section includes both the silty Lower Pilot Shale and the black fissile shale of the Upper Pilot Shale. The Lower Pilot Shale contains *Cyrtospirifer* at these localities.

At Alamo 488.5 feet of silty and argillaceous rock have been tentatively assigned to the Pilot Shale. The Lower Pilot Shale of this area is 351.1 feet thick and is notable for greater thickness and the oc-

currence of sandstone, flint, and abundant non-calcareous quartzitic siltstone. The Upper Pilot Shale at Alamo, 137.4 feet thick, also differs from more northerly exposures of the unit and contains black argillaceous limestone in concretions and thin interbedded layers. No fossils were noted in the Pilot Shale at this locality.

In marked contrast to the rocks just discussed, the Early Mississippian Joana Limestone and Monte Cristo Limestone are remarkably uniform. At all localities the lower portions of these formations consist mostly of fine to medium-grained, gray or black crinoidal limestone in beds ranging from 2 to 20 feet thick. These rocks are generally foetid and may contain flint or chert nodules. One to 20 feet of nodular, crinoidal limestone with shaly partings may occur at the base and 6 inches to 1 foot of basal quartzite was observed at Hamilton, at Buck Pass, and in the Confusion Range of Utah. These rocks lie on a clear-cut plane surface wherever observed and there is no interbedding of the Mississippian crinoidal limestone with any of the older rocks.

CONCLUSIONS AND PROBLEMS

The most important conclusion of this study is that the non-resistant, buff-weathering, poorly exposed rocks between the Late Devonian cliff-forming carbonate beds and the Early Mississippian crinoidal limestone may profitably be assigned to at least three rock units—West Range Limestone, Lower Pilot Shale, and Upper Pilot Shale. In addi-

tion, all except the Upper Pilot Shale contain Devonian brachiopods. These units appear conformable with and in part show intertonguing relationships with the underlying Devonian carbonate rocks, but a discontinuity is present below the Mississippian crinoidal limestone. Overlap of the detrital rocks by the Joana and/or Monte Cristo Limestone in the Cherry Creek-Pequop-Gold Hill Area and on the shelf in southern Nevada indicates earlier positivism on the shelf and in a large area of northeastern Nevada. This conclusion is reinforced by facies changes toward more and coarser detrital material in the upper Guilmette Limestone to Lower Pilot Shale interval in these areas. Local, pre-Joana positivism is also indicated in the Duckwater, Lund, and Cave Valley region.

At this stage in the development of our knowledge of the latest Devonian and earliest Mississippian history of eastern Nevada several problems seem to have clear priority for further investigation. The Late Devonian faunas require systematic description and thorough stratigraphic study in order that the various facies of the Late Devonian formations may be placed in a biostratigraphic and temporal relationship. The details of the complex facies relationships between the Guilmette Limestone, West Range Limestone, and Pilot Shale are still not adequately understood. Finally, a thorough search for fossils, including the less widely studied groups, must be made in the Upper Pilot Shale if its age is to be definitely determined.

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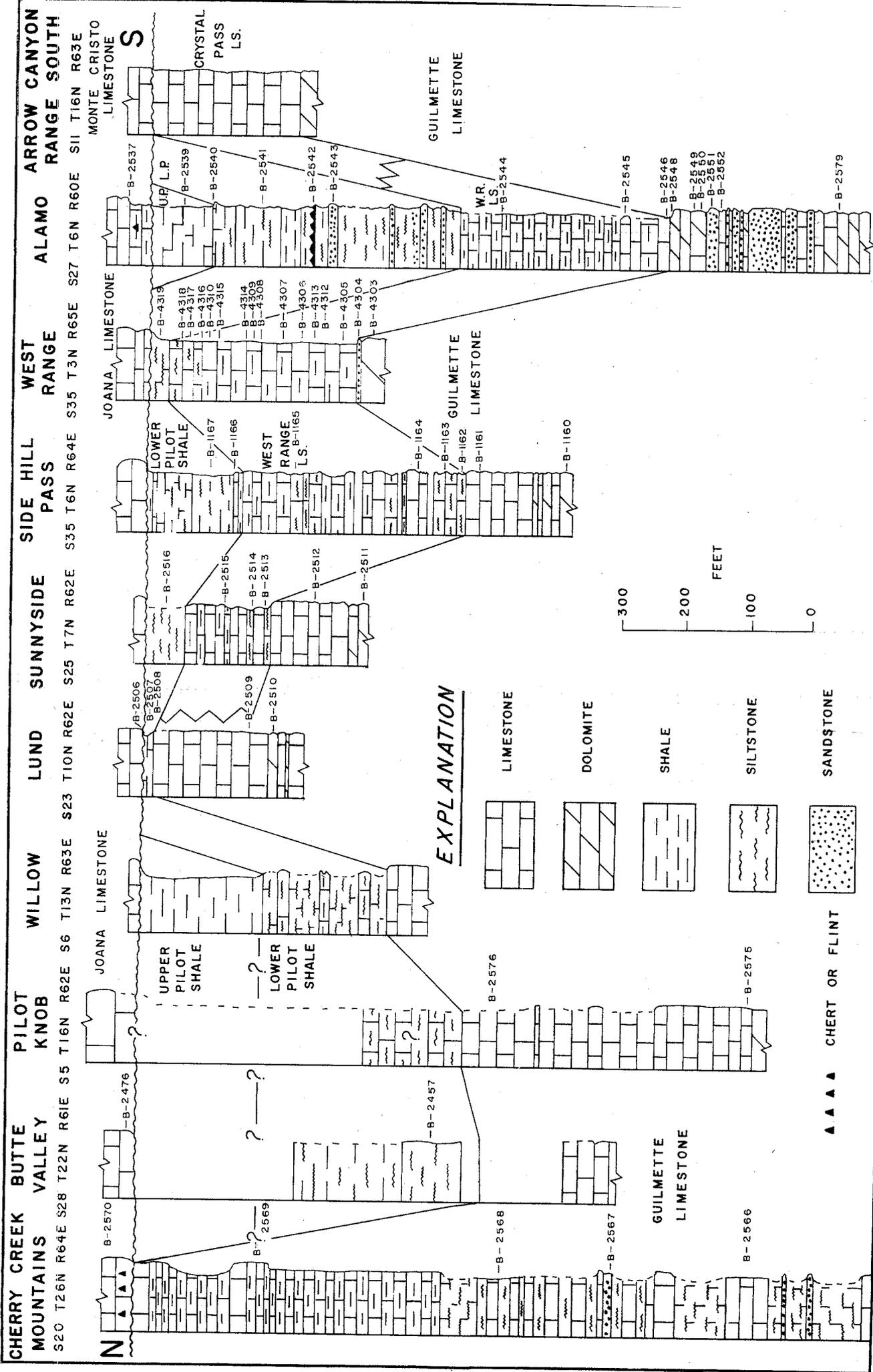


Fig. 3.—Stratigraphic sections of Late Devonian rocks in eastern Nevada.