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LATE DEVONIAN TECTONISM IN SOUTHEASTERN ARIZONA[1]

by

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Abstract

Devonian strata in southeastern Arizona are assigned to the lower Upper Devonian (Frasnian) Martin Formation and the upper Upper Devonian (Famennian) Percha Formation. The name Percha Formation is here proposed for the sequence of slope-forming shales with overlying ledgy carbonates that occurs above the Martin Formation throughout much of southern Arizona. Results of recent stratigraphic investigations of the Devonian show that some adjacent areas received greatly contrasting kinds and amounts of sediments and suggest that parts of the region may have been tectonically unstable during the Devonian. In order to more precisely determine the nature and location of Late Devonian structural changes, separate isopach maps wore prepared for the Frasnian and Famennian. The Frasnian map reveals the presence of a relatively narrow positive element, the southwestern extension of the Defiance Positive area, extending from the Clifton-Morenci *area* to near Winkelman. Comparison of Frasnian and Famennian isopach maps reveals that the Percha Formation attains its maximum thicknesses in a basin, or basins, which developed over the site of the preexisting positive area and whose limits coincide almost precisely with those of the positive area, The post-Martin, pre-Percha subsidence of the Frasnian positive element an the accompanying broad regional uplift of the Frasnian basins occurred in the early-middle Famennian and coincides with the beginnings of the Antler Orogeny in Nevada.

Foreword

Tectonism has been defined as the structural behavior of an element of the earth's crust during, or between, major cycles of sedimentation (Krumbein and Sloss, 1963, p. 390). The combination of elements present, their relative geographic distribution, and the degree of tectonism in each all play a part in controlling the nature and thickness of the accumulating sediments.

Introduction

Although considerable data have been gathered pertaining to the Mesozoic and Cenozoic structural development of Arizona, little informa-

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tion is available regarding Paleozoic tectonic activity in the state. Early investigations of Arizona's Paleozoic tectonic history (Stoyanow, 1942; McKee, 1951) furnish little conclusive evidence in this regard because they lacked the detailed stratigraphic subdivision necessary to unravel its depositional and structural history. Ross (1973) provided some of **the** necessary stratigraphic refinement when he subdivided the Pennsylvanian-Lower Permian strata of southeastern Arizona into 14 unconformity-bounded stratigraphic units, dated them using fusulinids, and worked out the complex depositional **and tectonic history of the region. Other such comprehensive investigations are reouired if we** hope **to work out** the **structural behavior and evolution of Arizona for** the **remainder of the** Paleozoic.

The present study is an **outgrowth of a** regional **study of the stratigraphy, biostratigraphy,** and **paleoecology** of the Devonian **System in Arizona. Most** of the data and new interpretations presented in this paper **are** based on 35 stratigraphic sections in a six-county area in southeastern Arizona (Fig. 1). Approximately half of these sections were measured or remeasured, described, and sampled for conodonts. For the remainder, stratigraphic data were obtained **from the references cited in Table 1.**

The interpretation of the Late Devonian structural history of southeastern Arizona presented in this paper is accomplished through the use of isopach maps based on the data in Table 1. Since isopach maps show the varying thickness of a stratigraphic unit by contour lines **drawn through** points of equal thickness, they can be used as a record of tectonism contemporaneous with the accumulation of the stratigraphic unit. A series of isopach maps based on successive stratigraphic units provides fundamental data on the sequence of structural changes that occurred in an area. By preparing a succession of isopach maps, the structural growth of an area can be developed in detail and the times of deformation narrowed to a specific stratigraphic interval. This is what we proposed to do for the Late Devonian of southeastern Arizona.

Stratiqraphic Nomenclature

Devonian strata in southeastern Arizona are assigned to the lower Upper Devonian (Frasnian) Martin Formation and the upper Upper Devonian (Famennian) Percha Formation. The Martin Formation was named by Ransome (1904) for a predominantly carbonate sequence between the Cambrian Abrigo Formation and the Mississippian Escabrosa Limestone in the Bisbee area. Subsequently the name Martin Formation has been applied to equivalent strata in southern and central Arizona by Ransome (1916), Stoyanow (1936), and Huddle and Dobrovolny (1952). Gordon (1907) assigned the name Percha Shale **to the Devonian sediments in the Kingston-Hillsboro-Lake Valley district** of **southwestern New Mexico. Stevenson (1945) divided the Percha Shale into** a lower Ready Pay member **consisting of fissile black shale and an upper Box member consisting of yellowish to greenish-gray shales with limestone nodules and shaly** limestones near the top.**

The name Percha Formation is here applied for the first time for the sequence of slope-forming shales and siltstones with overlying ledgy carbonates that occurs above the Martin Formation and is well developed in the Mescal, Dripping Spring, and Galiuro Mountains (Figs. 2, 3). Stoyanow (1936) first recognized the distinctive nature of these strata **and proposed they be assigned to a separate formation, the Lower Ouray Formation, because of the presence of the brachiopod** **Paurorhyncha endlichi** **(Meek), which is common in the lower Ouray** Limestone of

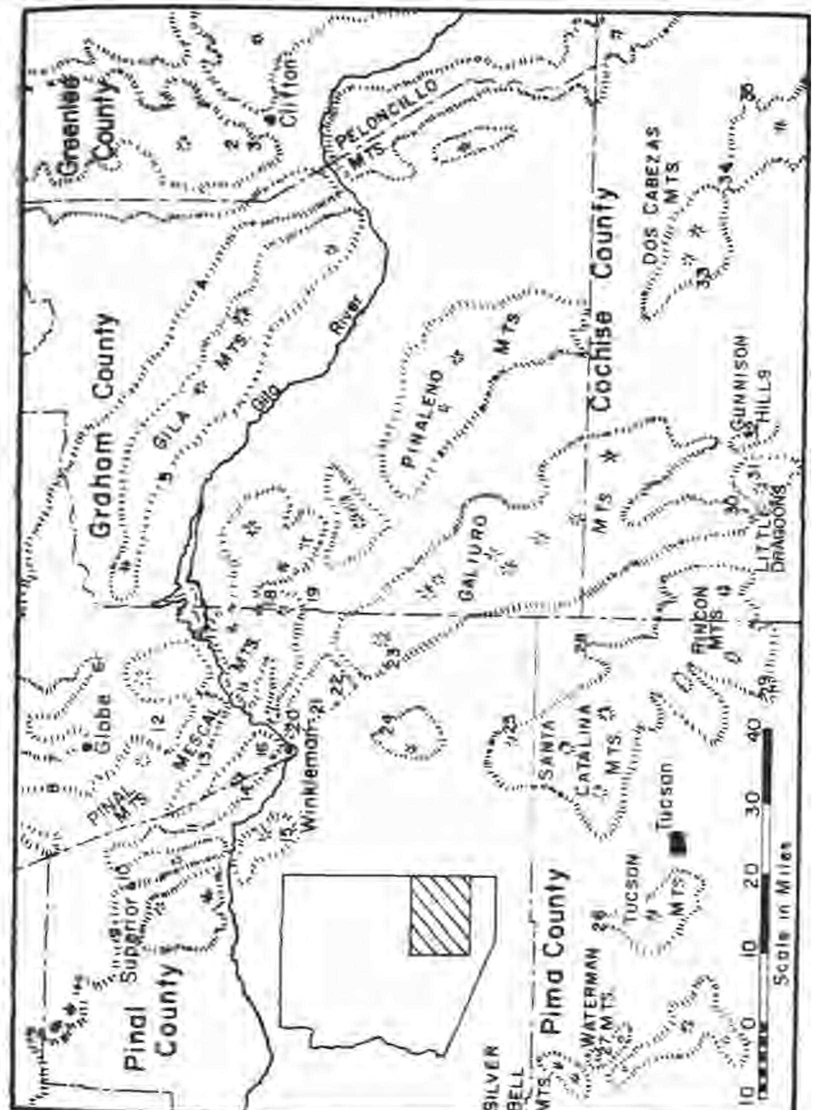

Table 1. List of localities

No.	Name	Reference	Thickness (ft) Martin-Percha
1.	San Francisco River	Pine; this study	56-120
2.	Highway 666	Pine; this study	6-140
3.	Morenci	*Pine; this study*	105-105
4.	Point of Pines	Pine	0-225
5.	Calva	Pine	0-0
6.	Job Corps Camp	Pine; this study	374-62
7.	Pinal Creek	Pine; this study	232+-50
8.	Sleeping Beauty	Pine	370-53
9.	Roblas Canyon	Pine	392-67
10.	Superior	Pine; this study	352-33
11.	Ray	Pine	373-45
12.	Ranch Creek	Pine	310-55
13.	Highway 77	Pine; this study	323-70
14.	Steamboat Mountain	Pine; this study	302-118
15.	Jim Thomas Wash	Pine	230-15
16.	Tornado Peak	Huddle & Dobrovolny	212-112
17.	Coolidge Dam	Pine	88-50
18.	Copper Reef Mountain	Pine	C-80
19.	Aravaipa	Simons	C-140+
20.	Saddle Mountain	this study	C-16C
21.	Kelley Camp	Pine	C-108
22.	Brandenburg Mountain	this study	40-245
23.	Holy Joe Peak	Pine; this study	5?-187
24.	Putnam Wash	Pine	36-129
25.	Peppersauce Wash	Stoyanow; this study	84-150?
26.	Twin Peaks	Stoyanow	245-0
27.	Waterman Mountains	Wright; this study	340-0
28.	Buehman Canyon	Wright	254-0
29.	Colossal Cave	Wright; this study	290-0
30.	Deepwell Ranch	Wright	226-0
31.	Little Dragoons	Wright	129-25?
32.	Gunnison Hills	Wright	226-14
33.	Dos Cabezas	Wright; this study	298-0
34.	Apache Pass	Wright; this study	325-0?
35.	Blue Mountain	Sabins; this study	150?-200?

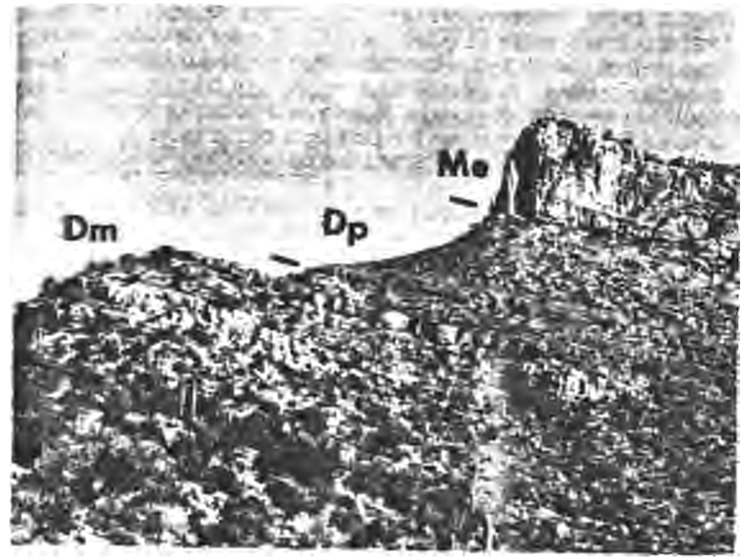

Figure 2. Steamboat Mountain, Locality 14, showing Martin (Dm) and Percha (Dp) Formations and the Escabrosa Limestone (Me)

Figure 3. Brandenburg Mountain, Locality 22, showing typical expression of Percha Formation (Dp) in southeast Arizona

Colorado. Because Stoyanow's Lower Ouray Formation was defined by its faunal characteristics rather than by its lithologic and stratigraphic characteristics, the name was never accepted and subsequent workers included these strata within the Martin Formation (Huddle and Dobrovolny, 1952; Wright, 1964; Teichert, 1965; Pine, 1968; Krieger, 1968a, 1968b, 1968c, 1968d). The results of more recent and more detailed stratigraphic and paleontologic work by us indicate that these strata do indeed form a lithologically distinct, mappable unit which can be recognized over much of southern Arizona. Because Stoyanow's name is invalid, we proposed the name Percha Formation for this unit because of its lithologic similarity to the Percha Shale of New Mexico *with* which it correlates.

Over the years, numerous names have been assigned to the Devonian rocks in central and southeastern Arizona, and most seem to apply to local faunal or facies zones. Two of these, the Morenci Shale and the Portal Formation, merit special comment since they correlate, at least in part, with the Percha Formation. Lindgren (1905) proposed the name Morenci Shale for the Upper Devonian strata in the Clifton-Morenci area. The upper 100+ feet are an olive-brown to reddish-brown shale called the Morenci shale, and the lower 50-100 feet are an argillaceous limestone named the Morenci limestone. The limestone, which may be missing locally, has yielded a lower Upper Devonian (Frasnian) conodont fauna. The shale is unfossiliferous but is considered by us to correlate with the shale member of the Percha Formation of southern and central Arizona and the Percha Shale of New Mexico. The Portal Formation was named by Sabins (1957) for a sequence of interbedded limestones and shales exposed in the Chiricahua Mountains near Portal, Arizona. The lower part of the Portal carries a lower Upper Devonian fauna (Ethington, 1965), but the higher beds, which resemble the Percha Shale, have not yet been adequately dated.

Stratigraphy of the Percha Formation

In southern Arizona, the Percha Formation can be subdivided into two informal members, a lower shale member and an upper, predominantly carbonate member. The shale member makes up the main body of the formation and is the only member present at some localities. This member consists of a sequence of olive-green to yellowish- or reddish-brown, slope-forming shales, which tend to weather to small yellowish flakes. Thin beds of siltstone occur in the shale member and become more numerous near the top. Locally, below the shale, are several inches to one foot or more of hematitic quartz sandstone. This basal unit contains pebbles of quartz, phosphatic concretions, arthrodiran fish fragments, shark teeth, conodonts, and an occasional abraded brachiopod or coral that seems to have been derived from the underlying Martin Formation. Conodonts from the basal unit of the Percha Formation inthe Mescal Mountains (Locality 13) suggest assignment to the late Famennian Scaphignathus velifer Zone (Fig. 4). Thickness of the shale member ranges from less than 10 feet to more than 200 feet. In southeastern Arizona, the Percha Formation usually rests disconformably on the lower Upper Devonian Martin Formation, although locally it directly overlies the Cambrian Abrigo Formation (Localities 20, 21) or the Ordovician Longfellow Limestone (Localities 1, 2).

The upper member of the Percha Formation consists of yellowish-brown to pale-red to light-gray silty dolomite. dolomitic siltstone, and limestone. Individual beds range from thin bedded to thick bedded and are of moderate to high resistance. Spherical quartz nodules up to three inches in diameter occur in some beds. Fossils are locally abundant and include brachiopods, crinoids, bryozoa, sponges, and solitary rugose corals. Con[odo]nts and rhynchonellid brachiopods independently sugges[t]

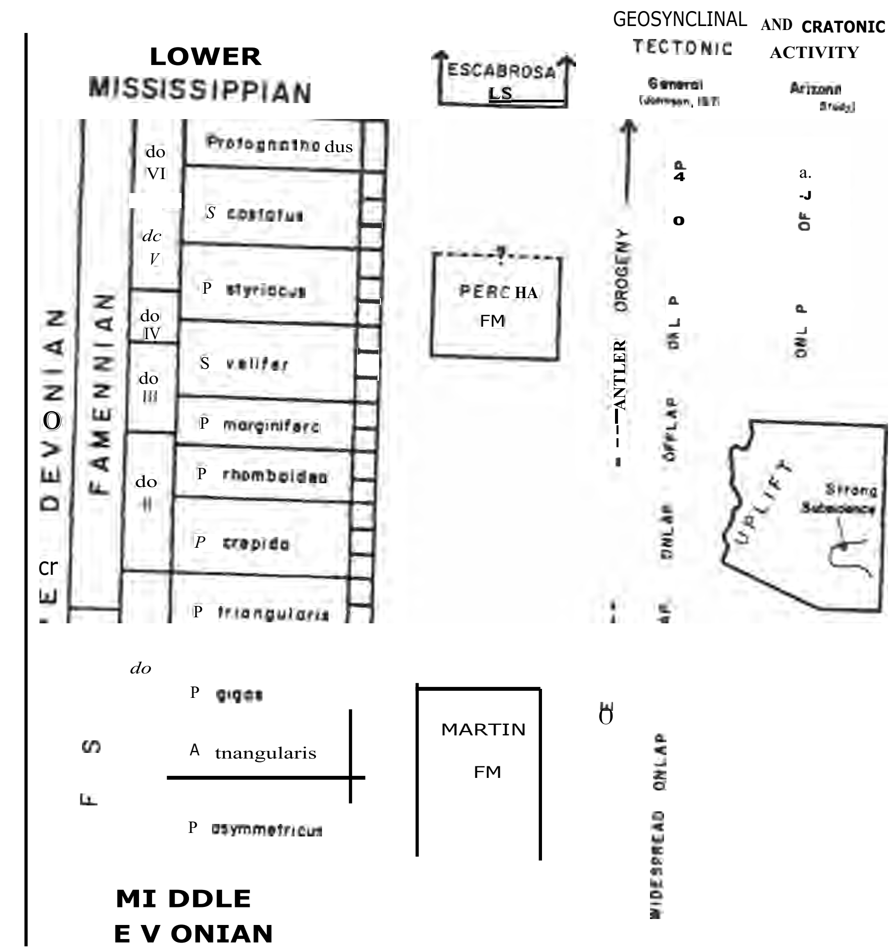

Figure 4. Upper Devonian conodont zones, ages of Martin and Percha Formations, and summary of Late Devonian tectonic activity. Conodont zones after Ziegler (1971), Klapper and others (1971), and Sandberg and Ziegler (1973).

a late Famennian age (Polygnathus styriacus Zone) for this member and correlation with the Ouray Limestone of Colorado and the Box member of the Percha Shale of New Mexico (Fig. 4 and Sandberg, 1976). The uppermost beds of the upper member of the Percha Formation consist of thick-bedded, light-gray, Escabrosa-like, dolomitic limestone. A thin quartz sandstone occurs at the base of the Escabrosa Limestone at several localities (Localities 14, 20, 22, 23). In the absence of this sandstone, the precise location of the upper contact becomes somewhat subjective. The upper member of the Percha Formation is not as widely distributed as the shale member and seems to prefer more basinal locations. Where present, its thickness ranges from 5 feet to more than 100 feet. Figure 5 illustrates the variation in thickness of the Martin Formation and the lower and upper members of the Percha Formation in southeastern Arizona.

Late Devonian Structural *History*

The structural development of an area is best shown when isopach maps for successive stratigraphic units are prepared and compared. We have done this for the lower Upper Devonian (Frasnian) Martin Formation and the upper Upper Devonian (Famennian) Percha Formation. The data upon which these maps are based are summarized in Table 1.

The tectonic framework of the area in the Frasnian is shown in Figure 6. The isopach map reveals the presence of a relatively narrow, east- and northeast-trending positive area extending from Winkelman to the Clifton-Morenci area. This positive area represents the southwestern extension of the Defiance Uplift and exposed Cambrian (Localities 20, 21) and Ordovician (Locality 2) strata at the surface. The 0-isopach that outlines the positive area could represent the limit of Martin deposition or could be the result of post-Martin erosion. The relatively uniform spacing of the contours and their general shape suggest that the 0-isopach approximates the strand *line* or depositional limit of the Martin Formation. South, west, and northwest of the positive area, the thickness of the Martin Formation increases rapidly to 300 feet and more.

The tectonic framework of the late Famennian is shown in Figure 7. Examination of the Famennian isopach map reveals an almost complete reversal of the location of basins and positive elements! The Percha Formation attains maximum thicknesses in a basin, or basins, that developed over the site of the preexisting positive area and whose limits coincide more or less precisely with those of the positive area. Figure 5 represents an approximate west-to-east cross section of Devonian strata from Superior to the Clifton-Morenci area. The abrupt changes in thickness that occur within the Upper Devonian near WInkelman dramatically affect the Martin Formation but have seemingly little effect on the Percha Formation.

The isopach maps and Figure 5 clearly demonstrate that maximum Famennian thickness occurs where Frasnian strata are greatly thinned or absent and indicate that post-Martin, pre-Percha structural changes resulted in an almost complete reversal of upwarping and downwarping in Arizona. What is the precise timing of the strong subsidence of the Frasnian positive element and the accompanying broad regional uplift of the former Frasnian basins? Conodont biostratigraphy of the Martin and Percha Formations (this study and Ethington, 1965) and Johnson's (1971) detailed analysis of the timing of geosynclinal tectonism and cratonic onlap-offlap sequences permit us to narrow the timing of this structural change to that part of the Famennian represented by the Palmatolepis rhomboides and Palmatolepis marginifera Zones (Fig. 4). Had it occurred slightly earlier in the Famennian, during a time of onlap, the newly formed basin would have received marine sediments of that age. The late

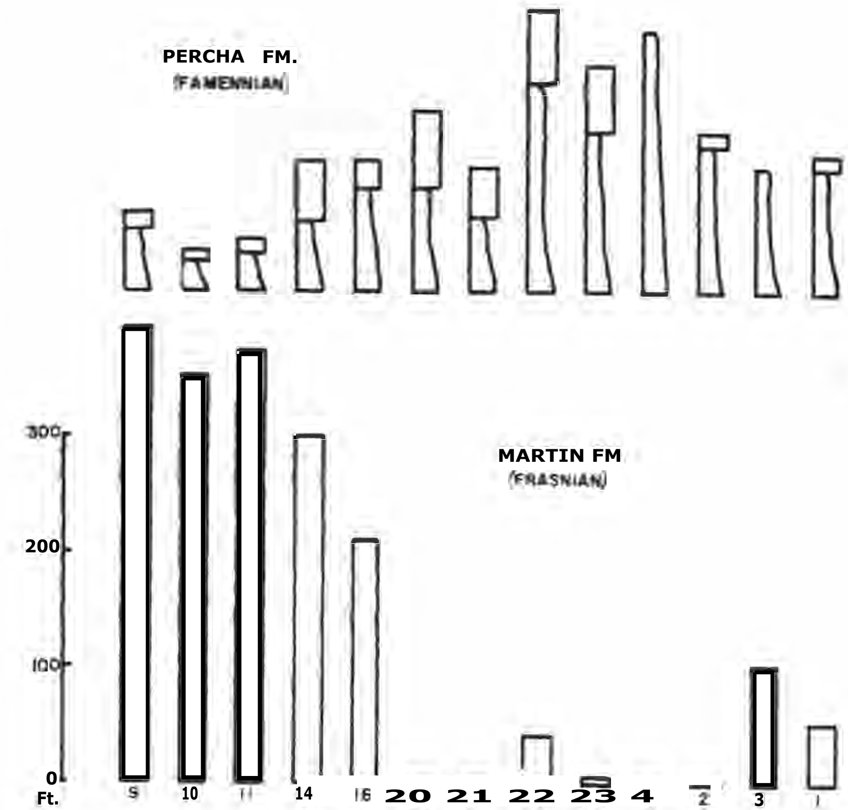

Figure 5. Thickness variation in Martin Formation and lower and upper members of Percha Formation between Superior and Clifton-Morenci area. Numbers refer to localities in Figure 1 and Table 1.

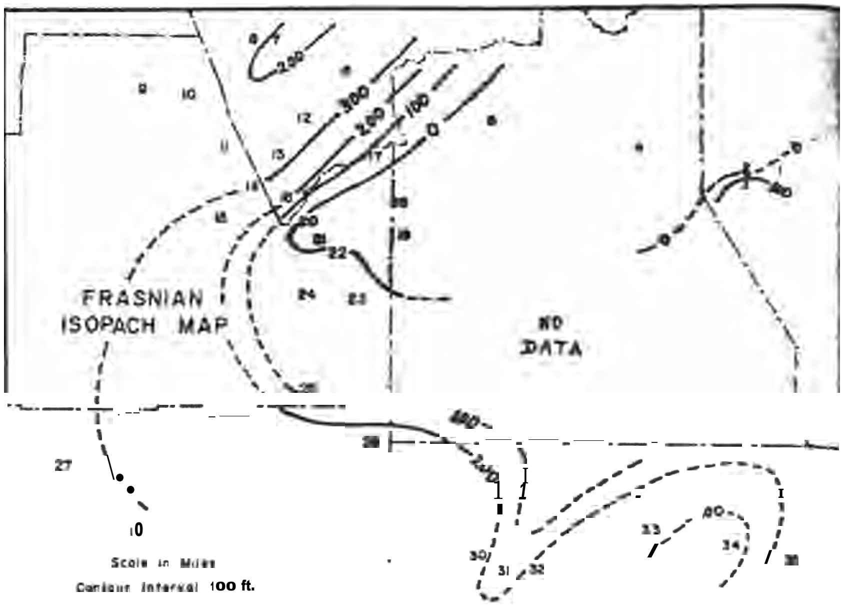

Figure 6. Isopach map for lower Upper Devonian Martin Formation. The inferred positive area is shaded.

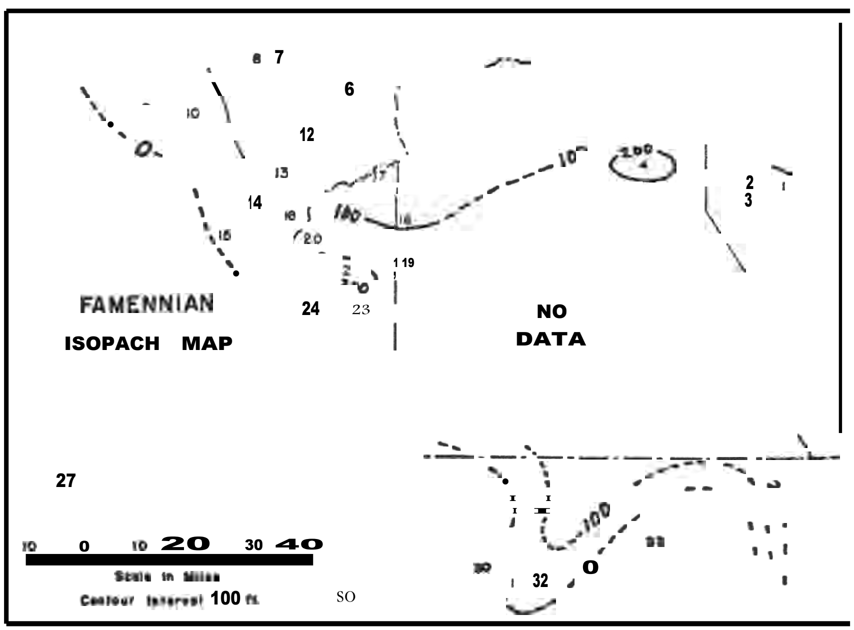

Figure 7. Isopach map for upper Upper Devonian Percha Formation. The inferred positive area is shaded.

Famennian onlap that deposited the shales and carbonates of the Percha Formation coincides with the time the Antler Orogeny reached its maximum intensity (Johnson, 1971).

Postcript

Pre-Mesozoic tectonic relations in southern Arizona are not well known because of a complex history of post-Paleozoic erosion, igneous intrusion, volcanism, thrusting, and block faulting in the region. We have demonstrated, as has Ross (1973) before us, that it is possible to work out the details of this region's Paleozoic structural development by preparing a series of isopach (and facies) maps for successive stratigraphic intervals of relatively short duration. In this way the structural growth of an area can be developed in detail and the times of deformation narrowed to specific stratigraphic intervals.

Acknowledgments

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