New Mexico Geological Society

Downloaded from: https://nmgs.nmt.edu/publications/guidebooks/29

Devonian stratigraphy and correlations in southeastern Arizona

Dietmar Schumacher

1978, pp. 175-181. https://doi.org/10.56577/FFC-29.175

in:

Land of Cochise (Southeastern Arizona), Callender, J. F.; Wilt, J.; Clemons, R. E.; James, H. L.; [eds.], New Mexico Geological Society 29 th Annual Fall Field Conference Guidebook, 348 p. https://doi.org/10.56577/FFC-29

This is one of many related papers that were included in the 1978 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

This page is intentionally left blank to maintain order of facing pages.

DEVONIAN STRATIGRAPHY AND CORRELATIONS IN SOUTHEASTERN ARIZONA

DIETMAR SCHUMACHER
Phillips Petroleum Company
Bartlesville, Oklahoma

INTRODUCTION

Devonian strata in southeastern Arizona comprise a complex mosaic of interbedded dolomite, limestone, sandstone and shale which is widely exposed in the many mountain ranges of the area. Over the years, numerous names have been proposed for the Devonian rocks in central and southeastern Arizona based on lithologic and paleontologic characteristics and geographic distribution. Most of these names seem to apply to local faunal or facies zones and have not been recognized by subsequent workers, but five formation names have been widely adopted and remain in current usage. These are the Martin, Swisshelm, Portal, Morenci and Percha formations. The nomenclatural history of these formations has been reviewed by Pye (1959), Wright (1964), Teichert (1965) and Pine (1968). All these formations are of Late Devonian age, but their exact placement within the Upper Devonian has been uncertain because diagnostic macrofossils frequently are rare or absent. The age and correlation of the Martin and Percha formations in southern Arizona was discussed by Schumacher and others (1976); however the most complete regional synthesis is that of Poole and others (1967). The most current and comprehensive stratigraphic synthesis of Upper Devonian depositional complexes in the western United States by Sandberg and Poole (1977) unfortunately does not include central and southern Arizona within its study area; however, their detailed maps and discussions are critical for anyone interested in the Devonian or Mississippian of Arizona.

The purpose of this paper is to summarize the nomenclature, dating and correlation of the Devonian formations of southern Arizona. Most of the data and new interpretations presented here are based on the results of recent stratigraphic and biostratigraphic investigations of the Devonian System in southern Arizona by Witter (1976), S. Meader (1976), Schumacher and others (1976), N. Meader (1977), Boyd (1978) and Schumacher and Witter (in preparation). The data summarized here are based on 54 principal stratigraphic sections (fig. 1 and Table 1) distributed across an area of more than 82,000 km^2 (36,000 mi^2) that extends from the Mexican border north to the Salt River, and from the New Mexico border west to the Vekol Mountains.

Conodonts have played a vital role in interpreting Devonian stratigraphy. This has been made possible by significant advances in refining the Upper Devonian conodont zonation proposed and emended by Zeigler (1962, 1971) (see Sandberg and Poole, 1977, p. 148) and recent developments concerning our understanding of conodant biofacies and paleoecology (Seddon and Sweet, 1971; Sandberg, 1976; Schumacher, 1976; Klapper and Barrick, 1978). The standard Upper Devonian conodant zonation now consists of 28 zones, some of which can be subdivided laterally into 3-5 biofacies. The application of this highly refined zonation in southern Arizona has greatly clarified age relations and correlations within the Upper Devonian.

STRATIGRAPHY AND CORRELATION

Martin Formation

Upper Devonian rocks throughout most of southern Arizona are assigned to the Martin Formation. Ransome (1904) proposed the name Martin Limestone 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). Teichert (1965) subdivided the Martin Formation of central Arizona into the Beckers Butte Sandstone Member and the overlying Jerome Member. The Jerome was further subdivided, in ascending stratigraphic order, into the fetid dolomite unit, the aphanitic dolomite unit and a lithologically heterogeneous upper unit. Pine (1968) extended Teichert's subdivisions into south-central Arizona. Schumacher and others (1976) demonstrated that part of Teichert's upper unit is considerably younger than the remainder of the Martin Formation and in fact disconformably overlies typical Martin strata in much of southeastern Arizona, locally resting directly on Cambrian or Ordovician strata. Schumacher and others (1976) recommended these strata be removed from the Martin Formation and assigned to the Percha Formation. This recommendation is followed here since the Martin Formation, thus restricted, forms a more natural stratigraphic unit and can be recognized throughout the study area. Based on the invertebrate macrofossils and conodonts, the Martin Formation is assignable to the lower Upper Devonian (Frasnian), although the basal beds may locally be slightly older (Stoyanow, 1936; Ethington, 1965; Witter, 1976; Schumacher and others, 1975; N. Meader, 1977).

Percha Formation (Arizona)

Schumacher and others (1976) proposed the name Percha Formation for a 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. Sandstone replaces all or part of the shale unit of the Percha Formation in the Whetstone, Rincon, Santa Catalina, Slate and Vekol mountains. 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,* which is common in the lower Ouray Limestone of southwestern 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. Because Stoyanow's name was invalid, Schumacher and others (1976) proposed the name Percha Forma-

tion for this unit because of its lithologic similarity to the Percha Shale (Box Member) of New Mexico with which it correlates. The present study confirms that these strata do indeed form a lithologically distinct, mappable unit which can be recognized over most of southern Arizona. Conodonts and rhynchonellid brachiopods independently suggest an upper Upper Devonian (Famennian) stratigraphic assignment for the Percha Formation (Stoyanow, 1936; Stainbrook, 1947; Ethington, 1965; Witter, 1976; S. Meader, 1976; Schumacher and others, 1976; Schumacher and Witter, in preparation).

Swisshelm Formation

Upper Devonian strata in the Swisshelm and Pedregosa mountains have been assigned to the Swisshelm Formation by Epis and others (1957). Lithologically, the Swisshelm Formation most closely resembles the Martin Formation, differing only in the predominance of sandstone and siltstone over carbonate rocks and shale. The upper one-third of the formation is largely impure limestone and shale, whereas quartz sandstone, siltstone and minor dolomitic limestone predominate in the lower two-thirds. Both conodonts and macrofossils indicate that the lower two-thirds of the formation is assignable to the uppermost Middle Devonian to lower Upper Devonian (upper Givetian to Frasnian). The upper third of the formation has yielded an upper Upper Devonian (Famennian) conodont fauna (Schumacher and Witter, in preparation; Boyd, 1978).

Portal Formation

Sabins (1957) assigned the name Portal Formation to a sequence of interbedded calcareous and siliceous shales and

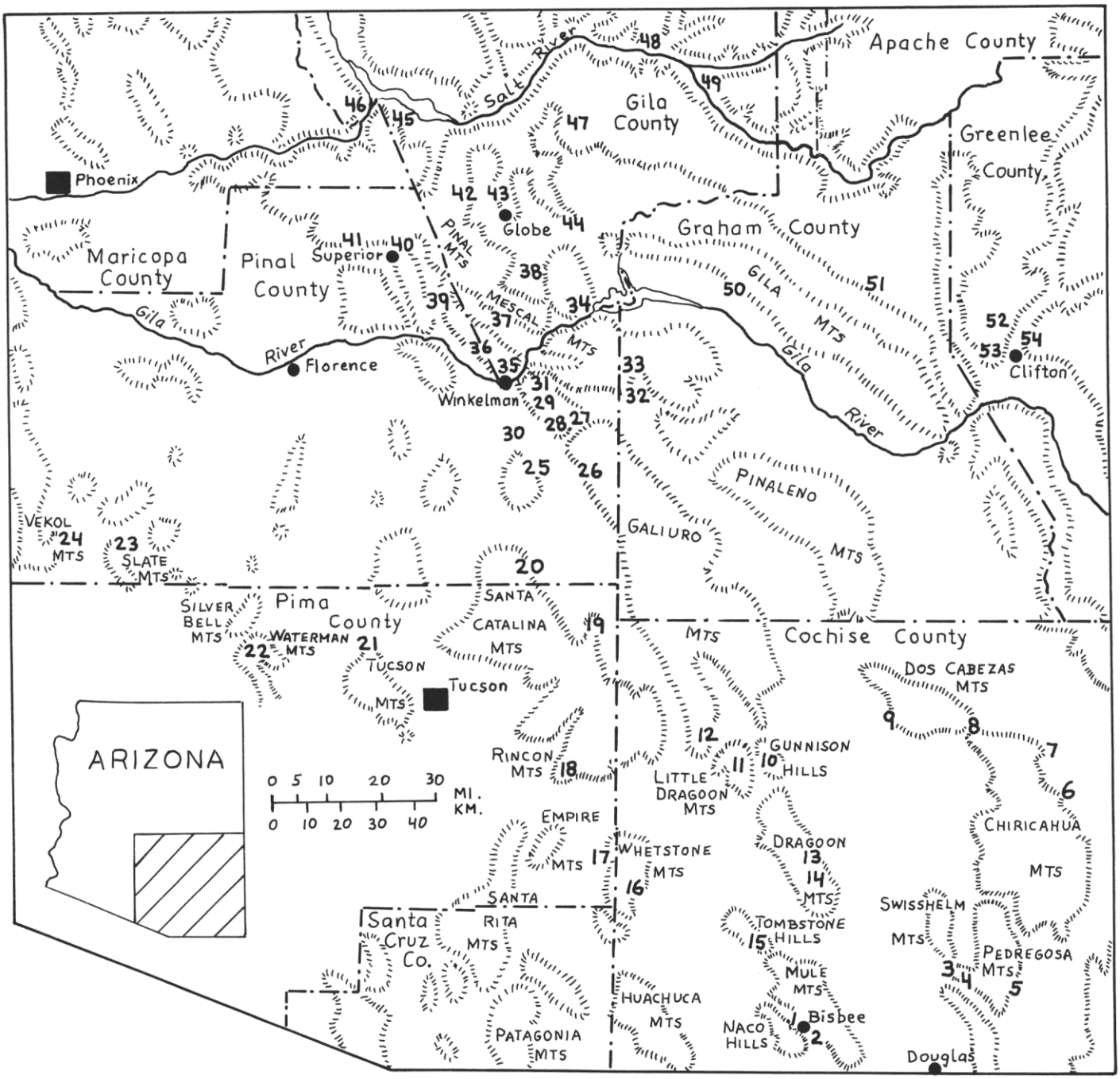

Figure 1. Map of southeastern Arizona showing locations of Devonian sections listed in Table 1.

Table 1. List of Localities

	LOCALITY	THICKNESS IN METERS FRASNIAN	FAMENNIAN	REFERENCES
1.	Mount Martin	117	23	Hayes and Landis, 1965
2.	Black Gap	67	21	Hayes and Landis, 1965; Boyd, 1978
3.	Leslie Pass	102	61	Epis and others, 1957; Boyd, 1978
4.	Castle Dome	105	64	Epis and others, 1957
5.	Boss Ranch	72	53	Epis and others, 1957; Boyd, 1978
6.	Portal	30	73	Sabins, 1957
7.	Blue Mountain	38	59	Sabins, 1957
8.	Apache Pass	18	55	Sabins, 1957
9.	Dos Cabezas	21	46	Schumacher and Witter, unpublished
10.	Gunnison Hills	75	8	Cooper and Silver, 1964
11.	Little Dragoons	74	10	Cooper and Silver, 1964
12.	Johnny Lyon Hills	64	17	Cooper and Silver, 1964
13.	Cochise Stronghold	81	0	LeMone, 1958
14.	Black Diamond	83	0	Gilluly, 1956
15.	Tombstone Hills	55	15	Gilluly, 1965
16.	Dry Canyon	101	21	Schumacher, unpublished
17.	J-6 Ranch	52	18	Schumacher and Witter, unpublished
18.,	Colossal Cave	73	15	Wright, 1964; Schumacher, unpublished
19.	Buehman Canyon	55	22	Wright, 1964
20.	Peppersauce Wash	44	46	Stoyanow, 1936
21.	Picacho de Calero	102	0	Stoyanow, 1936
22.	Waterman Mountains	103	0	Wright, 1964
23.	Slate Mountains	55	16	Wright, 1964; Schumacher, unpublished
24.	Vekol Mountains	61	11	Carpenter, 1947
25.	Putnam Wash	11	39	Krieger, 1968
26.	Holy Joe Peak	9	57	Witter, 1976; S. Meader, 1976
27.	Brandenburg II	9	75	Witter, 1976; S. Meader, 1976
28.	Brandenburg I	18	58	Witter, 1976; S. Meader, 1976
29.	Kelley Camp	0	33	Pine, 1968
30.	Tortilla Mountains	0	30	Krieger, 1974
31.	Saddle Mountain	0	49	Witter, 1976; S. Meader, 1976
32.	Aravai pa	0	43	Simons, 1964
33.	Copper Reef Mountain	0	43	Pine, 1968
34.	Coolidge Dam	27	15	Pine, 1968
35.	Tornado Peak	65	34	Huddle and Dobrolvny, 1952
36.	Steamboat Mountain	92	36	Witter, 1976; S. Meader, 1976
37.	Highway 77	98	27	Pine, 1968; Witter, 1976
38.	Ranch Creek	94	17	Pine, 1968
39.	Ray	114	14	Pine, 1968
40.	Superior	107	10	Pine, 1968
41.	Roblas Canyon	119	20	Pine, 1968
42.	Sleeping Beauty	113	16	Pine, 1968
43.	Pinal Creek	71+	15	Pine, 1968; N. Meader, 1977
44.	Job Corps Camp	114	19	Pine, 1968; Witter, 1976
45.	Windy Hill	97+	20	Teichert, 1965
46.	Roosevelt Dam	115	18	Teichert, 1965; N. Meader, 1977
47.	Seven Mile Creek	66	13	Teichert, 1965
48.	Flying V Canyon	95	15	Teichert, 1965
49.	Black River	99	8	Huddle and Dobrovolny, 1952
50.	Calva	0	0	Pine, 1968
51.	Point of Pines	0	69	Pine, 1968
52.	Highway 666	0	43	Pine, 1968
53.	Morenci	32	32	Pine, 1968
54.	Ash Spring Canyon	17	37	Pine, 1968; Schumacher, unpublished

limestone exposed in the Chiricahua and Dos Cabezas mountains. Sabins further subdivided the formation into four members. In ascending stratigraphic order, these are: Member 1, calcareous gray shale and thin-bedded to nodular gray micritic limestone; Member 2, black siliceous shale; Member 3, calcareous gray shale and thin-bedded to nodular gray micritic limestone; and Member 4, thick-bedded biosparitic limestone with thin intervals of gray shale. The Portal Formation is lithologically intermediate between the Percha Shale to the east and the Martin and Swisshelm formations to the west and south. Diagnostic macrofossils are scarce, but conodonts have been recovered from three of the four members. Member 1 is assignable to the lower Upper Devonian (Frasnian) and is possibly entirely of late Frasnian age (Ethington, 1965; Schumacher and Witter, in preparation). Members 3 and 4 have yielded conodonts indicative of the upper Upper Devonian (Famennian). Member 2 has not yet yielded diagnostic fossils, but regional stratigraphic relations and its gradational contact with Member 3 suggest it is of Famennian age.

Morenci Formation

The Morenci Formation was proposed by Lindgren (1905) for Upper Devonian strata in the Clifton-Morenci area of Arizona. The upper 30-50 m is an olive-brown to reddish-brown shale called the Morenci shale, and the lower 15-30 m is an argillaceous limestone named the Morenci limestone. The limestone, which may be locally absent, has yielded a lower Upper Devonian (Frasnian) conodont fauna (Schumacher and others, 1976). The shale is unfossiliferous, but regional stratigraphic relations suggest it correlates with the shale member of the Percha Formation to the west and with the Percha Shale to the east in New Mexico.

Percha Shale (New Mexico)

Gordon (1907) assigned the name Percha Shale to Devonian strata in the Kingston-Hillsboro-Lake Valley district of southwestern New Mexico. Stevenson (1945) divided the Percha Shale into a lower Ready Pay Member consisting predominantly of fissile black shale and an upper Box Member consisting of yellowish to greenish-gray shales with overlying limestone nodules and shaly limestones. Diagnostic fossils are rare in the Ready Pay Member, but Sandberg (1975, personal commun.) has reported conodonts indicative of the upper Grasnian *Palmatolepts gigas* Zone. Brachiopods (Stainbrook, 1947; S. Meader, 1976) and conodonts (Sandberg, 1976) from the Box Member independently indicate assignment to the upper Upper Devonian (Famennian).

DEPOSITIONAL COMPLEXES

Figure 2 summarizes the age, correlation and stratigraphic nomenclature of Devonian rocks in southeastern Arizona and southwestern New Mexico. It can be seen from Figure 2 that Devonian strata in the study area can be naturally grouped into two Upper Devonian depositional complexes separated by a major regional unconformity of mid-Late Devonian age.

Lower Depositional Complex

The lower Upper Devonian (Frasnian) depositional complex

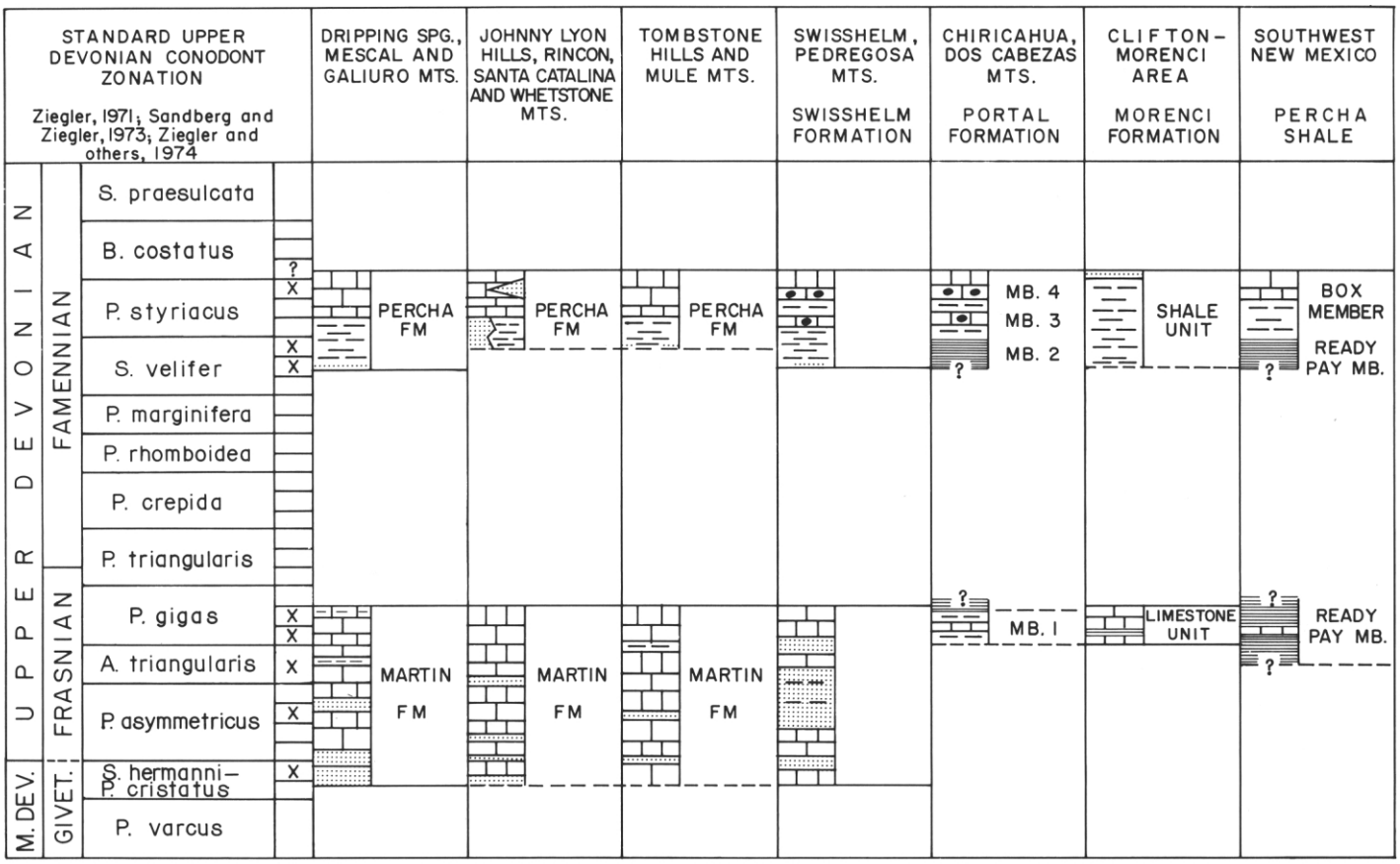

Figure 2. Age, correlation and stratigraphic nomenclature of Devonian rocks in southeastern Arizona and southwestern New Mexico. "X's" indicate conodont zones identified in southern Arizona. Stratigraphic columns are generalized and diagrammatic.

consists chiefly of limestone and dolomite with generally minor but increasing amounts of sandstone and shale southeastward. It includes the Martin Formation (restricted), the limestone unit of the Morenci Formation, the lower two-thirds of the Swisshelm Formation and the lower one-third of the Portal Formation. Paleoenvironments represented by the rocks of the lower depositional complex range from fluvial and tidal flat to lagoonal and carbonate platform with small patch reefs. Deep basinal muds are rare but may be represented within the Portal Formation and Morenci limestone.

Upper and lower contacts of the lower depositional complex appear conformable in outcrop sections, but a significant hiatus is represented by each. Basal deposits of the lower depositional complex range in age from latest Middle Devonian or earliest Late Devonian (late Givetian-early Frasnian) over much of southern Arizona to late Frasnian in the Clifton-Morenci area and possibly also in the Chiricahua-Dos Cabezas mountains. The hiatus represented by the lower contact includes most of the Devonian as well as all or part of the Silurian, Ordovician and Cambrian. Regional relations emphasize this unconformable relationship since the lower depositional complex overlies progressively younger rocks eastward: Precambrian in the Globe-Superior area, Cambrian at most localities between Winkelman and Bisbee, Lower Ordovician in the Swisshelm-Dos Cabezas-Morencia area, and Upper Ordovician near Clifton. The uppermost beds of the lower depositional complex are almost everywhere of late Frasnian age *(Palmatolepis gigas* Zone). The hiatus represented by the upper contact encompasses about one-half of the Late Devonian. Throughout much of the study area the upper contact is represented by a hematitic pavement overlain by basal sand or conglomerate of the upper depositional complex.

The isopach map of the lower depositional complex (fig. 3) reveals the presence of a relatively narrow, east- and northeast-trending positive element extending from Winkelman to the Clifton-Morenci area. This positive element exposed Cambrian (localities 29-32) and Lower Ordovician (localities 51-52) strata at the surface during the Frasnian. In this regard it is particularly noteworthy that Witter (1976) has recovered abraded Lower Ordovician conodonts from a sandstone at the top of the Martin Formation on Holy Joe Peak (locality 26). The 0-isopach that outlines the positive element could represent the depositional limit of the lower depositional complex or it could be the result of subsequent erosion. The relatively uniform spacing of the contours and their general shape suggests that the 0-isopach approximates the strand line, or depositional limit, for most of its length. South, west and northwest of the positive area the thickness of the lower depositional complex increases rapidly to 100 m and more. This maximum thickness does not necessarily reflect a more offshore location or deeper water sedimentation, for N. Meader (1977) has documented that approximately one-third of the total thickness of the Roosevelt Dam section (locality 46) represents intertidal and supratidal deposits, and most of the remainder, shallow subtidal.

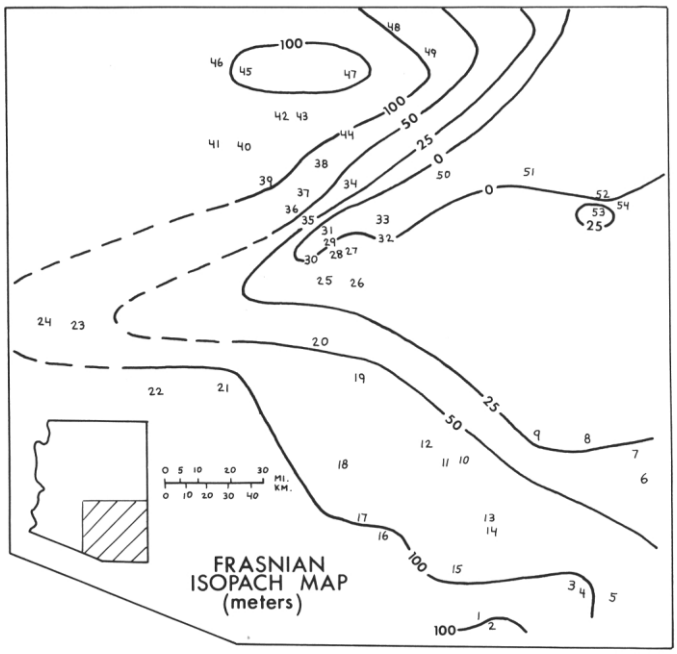

Figure 3. Isopach map of lower depositional complex showing thickness in meters; dashed where inferred. Contour intervals 25, 50 and 100 m. Small numbers are localities listed in Table 1.

Fossils diagnostic of the lower depositional complex include stromatoporoids; the corals *Hexagonaria, Pachyphyllum, Coenites;* the brachiopods *Atrypa, Spinatrypa, Stropheodonta, Theodosia;* and the conodonts *Ancyrodella, Ancyrognathus, Icriodus (I. alternatus, I. symmetricus), Palmatolepis (P. proversa, P. foliacea, P. subrecta, P. gigas), Polygnathus (P. pennatus, P. norrnalis, P. asymmetricus).*

Upper Depositional Complex

The upper Upper Devonian (middle-upper Famennian) depositional complex consists chiefly of yellowish-green to gray to black shales and overlying carbonates; however sandstones increase at the expense of shales at the more western localities. It includes the Arizona part of the Percha Formation, the shale unit of the Morenci Formation, the upper one-third of the Swisshelm Formation and the upper two-thirds of the Portal Formation. Paleoenvironments represented by the rocks of the upper depositional complex range from tidal flat (?) and lagoonal to carbonate platform. Deep basinal muds, if present, are restricted to the Portal Formation. The petrology and environments of deposition of the Percha Shale in southwestern New Mexico have recently been described by Kocurek (1977).

Upper and lower contacts of the upper depositional complex appear conformable in outcrop sections, but a significant hiatus is represented by each. The basal deposits of the upper depositional complex are generally shale or sandstone, and at many localities they directly overlie a hematitic pavement. The quartz sandstone and siltstone above this pavement contains pebbles of quartz, phosphatic pellets and nodules, abraded fish bones and teeth, and occasional abraded brachiopods and corals from the underlying formation (localities, 2, 3, 26-28, 37). These basal deposits range in age from the middle Famennian *Scaphignathus ve/ifer* Zone (Galiuro and Mescal Mountains) to the late Famennian *Polygnathus styriacus* Zone (Slate and Vekol mountains). The hiatus represented by the lower contact includes about one-half of the Late Devonian, or approximately 12 conodont zones (Witter, 1976; Schumacher and Witter, in preparation). This unconformable relationship is more evident when one examines regional stratigraphic relations, since the upper depositional complex rests on strata

ranging in age from early Late Devonian (most sections), to Early Ordovician at localities near Morenci (localities 51, 52), to Late Cambrian east of Winkelman (localities 29-33). The uppermost beds are almost everywhere assignable to the late Famennian *Polygnathus styriacus* Zone; however the lower part of the overlying *Bispathodus costatus* Zone may be locally present in the Galiuro and Chiricahua mountains. The upper contact can be difficult to place on purely lithologic criteria since the uppermost carbonates frequently consist of light-gray Escabrosa-like limestones. A thin sandstone occurs at the base of the Escabrosa at some localities, or at the top of the Percha Formation at others. In the absence of this sandstone the precise location of the upper contact becomes somewhat subjective. Despite the frequent lack of physical evidence, faunal evidence indicates that the upper contact represents a significant hiatus, including the latest Devonian and most or all of the Early Mississippian (Witter, 1976; Schumacher and Witter, in preparation). Additionally, recent biostratigraphic investigations of the Mississippian by Purves (1978) indicate that this hiatus increases in magnitude northward.

The isopach map for the upper depositional complex (fig. 4) reveals some striking differences from the Frasnian pattern. Examination of the two isopach maps reveals that maximum Famennian thickness occurs where Frasnian strata are greatly thinned or absent and indicates an almost complete reversal of upwarping and downwarping in southern Arizona during the early to middle Famennian. The 0-isopach in the western part of the map area appears to approximate the western depositional limit of the upper depositional complex, since nearby sections are thinner and sandier than sections elsewhere. North of the Clifton-Morenci area and to the south in the Dragoon Mountains, the 0-isopach appears to be due largely to pre-Mississippian erosion of upper depositional complex shales.

Fossils diagnostic of the upper depositional complex include the sponge *Ensiferites;* the brachiopods *Paurorhyncha, Leio productus, Syringospira, Cyrtospirifer (C. kindle/);* and the conodonts *Bispathodus, Icriodus (I. costatus), Palmatolepis (P distorta, P. perlobata, P. rugosa), Polygnathus (P. communis, P. homoirregularis, P. nodocostatus, P. perplexus. P. semicostaws).*

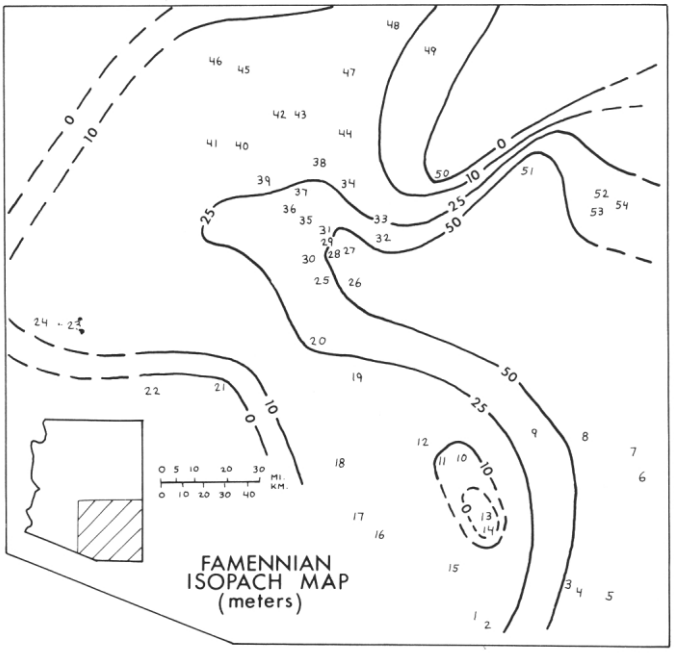

Figure 4. Isopach map of upper depositional complex showing thickness in meters; dashed where inferred. Contour intervals 10, 25 and 50 m. Small numbers are localities listed in Table 1.

SUMMARY AND CONCLUSIONS

The Late Devonian history in southern Arizona consists of two major depositional cycles separated by an interval of epeirogenic uplift and erosion. The lower Upper Devonian (Frasnian) depositional complex includes the Martin Formation, the limestone unit of the Morenci Formation and parts of the Swisshelm and Portal formations and correlates at least in part with the Ready Pay Member of the Percha Shale in New Mexico. The upper Upper Devonian (Famennian) depositional complex includes the Arizona part of the Percha Formation, the shale unit of the Morenci Formation, the upper one-third of the Swisshelm Formation and the upper two-thirds of the Portal Formation and correlates with the Box Member of the Percha Shale of New Mexico.

The Frasnian depositional complex was widely deposited across the western continental shelf and adjacent cratonic platform, including southern Arizona, during Taghanic onlap. The withdrawal of late Frasnian seas from Arizona coincides with an early pulse of the Antler orogeny and the formation of the Pilot basin in eastern Nevada and western Utah (Sandberg and Poole, 1977). Marine sedimentation resumed in southern Arizona in the latter part of the Famennian as increased Antler orogenic activity displaced the seaway eastward across the cratonic platform. This synchroneity of orogenic and transgressive events, previously discussed by Johnson (1971) and recently reviewed by Sandberg and Poole (1977), appears to have considerably influenced the character and distribution of the Arizona Devonian.

REFERENCES

Boyd, D. T., 1978, Stratigraphic relations within the Devonian Martin, Swisshelm, and Portal Formations in Cochise County, Arizona [M.S. thesis] : Tucson, Univ. Ariz., 76 p.

Carpenter, R. H., 1947, The geology and ore deposits of the Vekol Mountains, Pinal County, Arizona [Ph.D. dissertation]: Stanford, Calif., Stanford Univ., 110 p.

Cooper, J. R., and Silver, L. T., 1964, Geology and ore deposits of the Dragoon Quadrangle, Cochise County, Arizona: U.S. Geol. Survey Prof. Paper 416, 196 p.

Epis, R. C., Gilbert, C. M., and Langenheim, R. L., 1957, Upper Devonian Swisshelm Formation of southeast Arizona: Am. Assoc. Petrol. Geol. Bull., v. 41, p. 2243-2256.

Ethington, R. L., 1965, Late Devonian and Early Mississippian conodonts from Arizona and New Mexico: Jour. Paleontology, v. 39, p. 566-589.

Gilluly, J., 1956, General geology of central Cochise County, Arizona: U.S. Geol. Survey Prof. Paper 281, 169 p.

Gordon, C. H., 1907, Mississippian (lower Carboniferous) formations in the Rio Grande Valley, New Mexico: Am. Jour. Science, v. 24, p. 60-62.

Hayes, P. T., and Landis, E. R., 1965, Paleozoic stratigraphy of the southern Mule Mountains, Arizona: U.S. Geol. Survey Bull. 1201-F, p. 1-43.

Huddle, J. W., and Dobrovolny, E., 1952, Devonian and Mississippian rocks in central Arizona: U.S. Geol. Survey Prof. Paper 233-D, 112 P.

Johnson, J. G., 1971, Timing and coordination of orogenic, epeirogenic, and eustatic events: Geol. Soc. America Bull., v. 82, p. 3263-3298.

Klapper, G., and Barrick, J. E., 1978, Conodont ecology: pelagic versus benthic: Lethasia, v. 11, p. 15-23.

Kocurek, G., 1977, Petrology and environments of deposition of the Percha Formation, Upper Devonian, southwestern New Mexico [M.S. thesis] : Houston, Texas, Univ. Houston, 137 p.

Krieger, M. H., 1968, Geologic map of the Lookout Mountain Quadrangle, Pinal County, Arizona: U.S. Geol. Survey Map GQ-670.

----, 1974, Geologic map of the Putnam Wash Quadrangle, Pinal County, Arizona: U.S. Geol. Survey Map GQ-1109.

LeMone, D. V., 1958, The Devonian stratigraphy of Cochise, Pima, and Santa Cruz Counties, Arizona, and Hidalgo County, New Mexico [M.S. thesis] : Tucson, Univ. Ariz., 108 p.

Lindgren, W., 1905, The copper deposits of the Clifton-Morenci district, Arizona: U.S. Geol. Survey Prof. Paper 43, 375 p.

Meader, N. M., 1977, Paleoecology and paleoenvironments of the Upper Devonian Martin Formation in the Roosevelt Dam-Globe area, Gila County, Arizona [M.S. thesis] : Tucson, Univ. Ariz., 124 p.

Meader, S. J., 1976, Paleoecology of the Upper Devonian Percha Formation of south-central Arizona [M.S. thesis] : Tucson, Univ. Ariz., 104 p.

Pine, G. L., 1968, Devonian stratigraphy and paleogeography in Gila, Graham, Greenlee and Pinal Counties, Arizona [Ph.D. dissertation] : Tucson, Univ. Ariz., 305 p.

Poole, F. G., Baars, D. L., Drewes, H., Hayes, P. T., Ketner, K. B., McKee, E. D., Teichert, C., and Williams, J. S., 1967, Devonian of the southwestern United States, *in* Oswald, D. H. (ed.), International Symposium on the Devonian System, Calgary, Alberta: Calgary, Alberta Soc. Petrol. Geologists, v. 1, p. 879-912.

Purves, W. J., 1978, Paleoenvironmental evaluation of Mississippian-age carbonate rocks in central and southeastern Arizona [Ph.D. dissertation] : Tucson, Univ. Ariz., 672 p.

Pye, W. D., 1959, Silurian and Devonian stratigraphy, southeastern Arizona and southwestern New Mexico: Arizona Geol. Society Guidebook II, p. 25-30.

Ransome, F. L., 1904, The geology and ore deposits of the Bisbee quadrangle, Arizona: U.S. Geol. Survey Prof. Paper 21, 168 p.

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

Sabins, F. F., Jr., 1957, Stratigraphic relations in Chiricahua and Dos Cabezas Mountains, Arizona: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 466-510.

Sandberg, C. A., 1976, Conodont biofacies of Late Devonian *Polygnathus styriacus* Zone in western United States, *in* Barnes, C. R. (ed.), Symposium on conodont paleoecology: Geol. Assoc. Canada Special Paper 15, p. 171-186.

----, and Poole, FG., 1977, Conodont biostratigraphy and depositional complexes of Upper Devonian cratonic-platform and continental-shelf rocks in the Western United States, *in* Murphy, M. A., Berry, W. B. N., and Sandberg, C. A. (eds.), Western North America: Devonian: California University, Riverside, Campus Mus. Contr. 4, p. 144-182.

----, and Ziegler, W., 1973, Refinement of standard Upper Devonian conodont zonation based on sections in Nevada and West Germany: Geologica et Palaeontologica, v. 7, p. 97-122.

Schumacher, D., 1976, Conodont biofacies and paleoenvironments in Middle Devonian-Upper Devonian boundary beds, central Missouri, *in* Barnes, C. R. (ed.), Symposium on conodont paleoecology: Geol. Assoc. Canada Special Paper 15, p. 160-169.

----, Witter, D. P., Jr., Meader, S. J., and Keith, S. B., 1976, Late Devonian tectonism in southeastern Arizona: Arizona Geol. Society Digest, v. 10, p. 59-70.

Seddon, G., and Sweet, W. C., 1971, An ecologic model for conodonts: Jour. Paleontology, v. 45, p. 869-880.

Simons, S. F., 1964, Geology of the Klondyke Quadrangle, Graham and Pinal Counties, Arizona: U.S. Geol. Survey Prof. Paper 461, 173 p.

Stainbrook, M. A., 1947, Brachiopoda of the Percha shale of New Mexico and Arizona: Jour. Paleontology, v. 21, p. 297-328.

Stevenson, F. V., 1945, Devonian of New Mexico: Jour. Geology, v. 53, p. 217-245.

Stoyanow, A. A., 1936, Correlation of Arizona Paleozoic formations: Geol. Soc. America Bull., v. 47, p. 459-540.

Teichert, C., 1965, Devonian rocks and paleogeography of central Arizona: U.S. Geol. Survey Prof. Paper 464, 181 p.

Witter, D. P., Jr., 1976, Conodont biostratigraphy of the Upper Devonian in the Globe-Mammoth area, Arizona [M.S. thesis] : Tucson, Univ. Ariz., 98 p.

Wright, J. J., 1964, Petrology of the Devonian rocks in eastern Pima and Cochise Counties, Arizona [Ph.D. dissertation] : Tucson, Univ. Ariz., 153 p.

Ziegler, W., 1962, Taxionomie und Phylogenie Oberdevonischer Conodonten und ihre stratigraphische Bedeutung: Hess. Landesamt Bodenforschung Abh. 38, 166 p.

----, 1971, Conodont stratigraphy of the European Devonian, *in* Sweet, W. C., and Bergstrom, S. M. (eds.), Symposium on conodont biostratigraphy: Geol. Soc. America Memoir 127, p. 227-284.

----, Sandberg, C. A., and Austin, R. L., 1974, Revision of *Bispathodus* group (Conodonta) in the upper Devonian and Lower Carboniferous: Geologica et Palaeontologica, v. 8, p. 97-112.