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Cover image - Patch reef near the wall off Grotto Beach (photo by Lee Florea).

Upper Carboniferous (Pennsylvanian) and Lower Permian reefs: evolution, composition, paleogeography, and distribution

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1. Abstract

The spectrum of Upper Carboniferous (Pennsylvanian) and Lower Permian reef and mound communities varied in time and space. Late Paleozoic reef compositions were largely dependent on paleotemperature and light availability, which in turn were controlled by paleolatitude, paleobathymetry, and growth location. Shallow-water tropical and subtropical reef communities consisted largely of originally-aragonitic calcareous algae, calcisponges and submarine radial fibrous cements. Subtropical *Paleoaplysina*-phylloid algal buildups graded into cooler water buildups that were mudmounds constructed mainly by fenestrate bryozoans with varying amounts of *Tubiphytes*, crinoids, brachiopods, and radiaxial cementstones, all of which were calcitic. Deep and cold-water settings were characterized by siliceous sponge mounds, with varying amounts of calcitic brachiopods and bryozoans.

2. Introduction

The composition of reef biotas has varied greatly through different periods of Phanerozoic time (e.g., James 1983, fig. 63; James and Bourque 1992, fig. 35; Kiessling et al. 2002). Cambrian and Lower Ordovician (Early Paleozoic) organic carbonate buildups were constructed mainly by stromatolitic and thrombolitic microbial communities. Massive corals (rugosans and tabulates) and stromatoporoids evolved during the Ordovician, and during the following Silurian and Devonian Periods (Middle Paleozoic) coral-stromatoporoid communities constructed major reef systems. However, in the Late Devonian that reef community disappeared during a major global extinction event.

During subsequent Late Paleozoic time, very different types of carbonate buildup communities evolved (Wahlman 1988, 2002; West 1988). Following the Late Devonian extinction event, the Mississippian Period exhibited only minor shelfal reef development and carbonate buildups were mostly deeper-water mudmounds composed largely of fenestrate bryozoans, crinoids, microbialites and submarine cements (so-called Waulsortian mounds). During the Early Pennsylvanian Period, a variety of small calcareous algae (e.g., donezellids, *Cuniephycus*, codiacean green phylloid algae) built broad low mounds and banks. During the Middle and Late Pennsylvanian, phylloid green algae dominated tropical and subtropical, shallow-water carbonate buildup communities. That tropical algal-based buildup community radiated and diversified through latest Pennsylvanian and Early Permian time, and reached its acme of development in Middle Permian reef systems, such as the Capitan Reef exposed in the Guadalupe Mountains of west Texas and New Mexico (Newell et al. 1953; Babcock 1977; Saller et al. 1999). This paper summarizes the evolution and compositions of Pennsylvanian-Lower Permian reefs and mounds, and their variation through space and time.

2.1. Pennsylvanian-Lower Permian reefs and mounds

The Late Carboniferous (Pennsylvanian)- Early Permian was a time of Pangean supercontinent assembly and predominantly collisional tectonics, continental glaciation, and long-term reef evolution (Figures 1 and 2). The

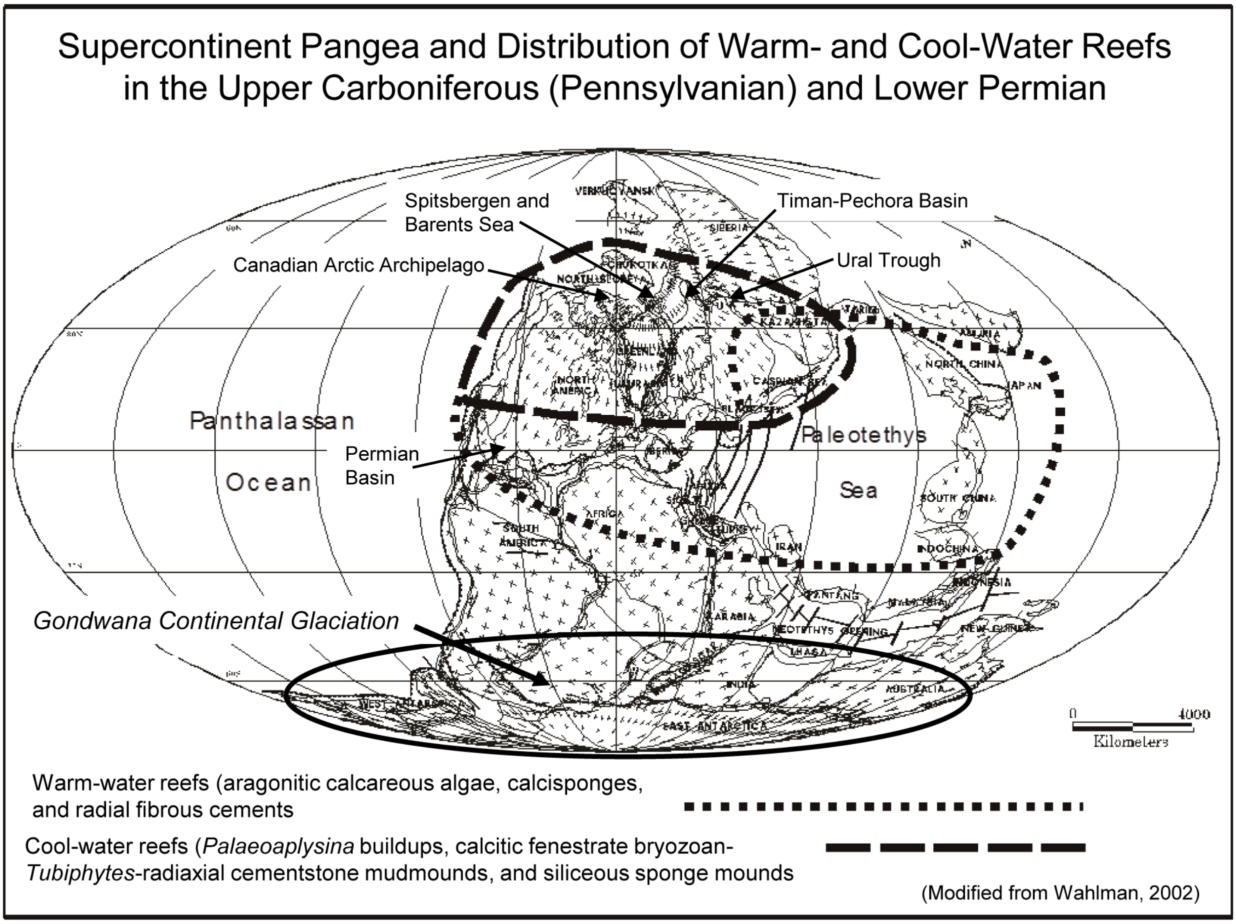

Figure 1. Upper Carboniferous-Lower Permian global paleogeographic map of the supercontinent Pangea showing the general distribution of tropical warm-water phylloid algal mounds and algal-calcisponge-cement reefs, and subtropical-temperate cooler-water *Palaeoaplysina* mounds and adjacent deeper-water fenestrate bryozoan-*Tubiphytes*-radiaxial cementstone reefs. There is considerable mixing of reef constituents along the transitional boundaries between the two paleobiogeographic realms, particularly along the Ural Trough, which opened at the north end to cool northern seas and at the south end to warm tropical seas. (Base map from Golonka 2002; map labeling modified from Wahlman 2002).

widespread collisional tectonics associated with the assembly of the supercontinent Pangea created and enhanced shelf and basin systems (Figure 1). Gondwanan south polar glaciation caused high-frequency glacioeustatic sea-level fluctuations that resulted in relatively complex "Icehouse" stratigraphic architectures and cyclothemic depositional sequences (Read et al. 1995; Kerans and Tinker 1997; Rankey et al. 1999). Organic carbonate buildups lacked large massive reef-building organisms, such as corals or stromatoporoids, but rather were constructed by relatively small organisms, such as diverse types of calcareous algae, calcareous sponges (inozoans, sphinctozoans, chaetetids), bryozoans (erect fenestellid and branching forms, and encrusting fistuliporids), and the microproblematicum *Tubiphytes* (Figure 2). Those communities mostly inhabited sub-wavebase paleoenvironments and shallowed upward from upper slope to shelf-margin settings (Wahlman and Tasker 2013). Microbialites and submarine cementation also often played significant roles in the construction of these buildups.

Pennsylvanian-Permian organic carbonate buildups consist of a spectrum of reef and mound types whose organic and inorganic

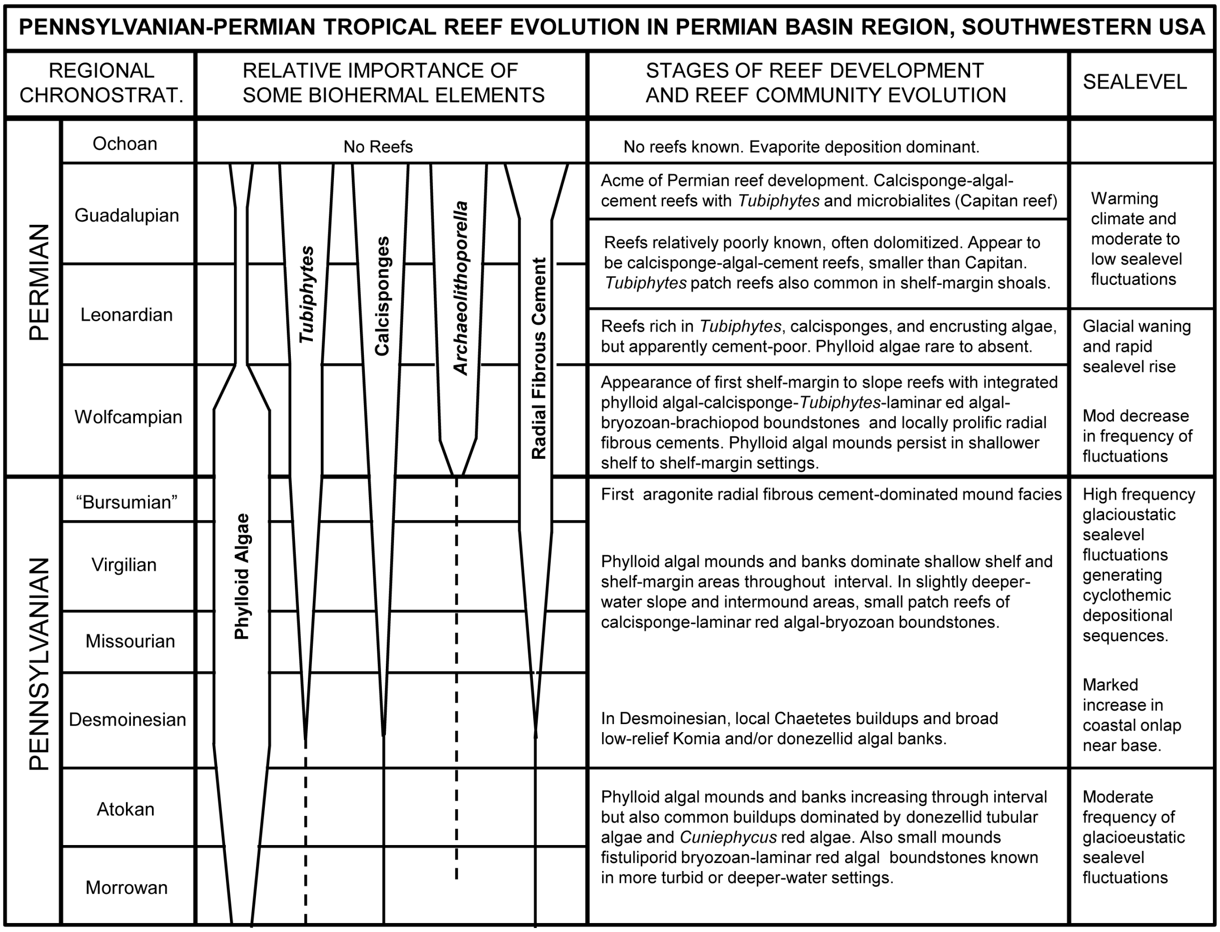

Figure 2. Chart summarizing the evolution and stratigraphic distribution of important elements of the Pennsylvanian-Permian tropical reef community in the Permian Basin region of the southwestern USA. Phylloid algal mounds and banks dominated shallow-water carbonate shelf and shelf-margin areas throughout the Pennsylvanian, but that community integrated with several other elements during the earliest Permian (Wolfcampian) to create the Permian reef community that reached its acme of development in the Middle Permian Capitan Reef of west Texas and New Mexico. (Modified from Wahlman 1988).

compositions were controlled mainly by seawater temperature and light availability, which in turn were related to paleolatitude and/or water depth, and paleogeographic growth position (Wahlman 2002; Wahlman and Konovalova 2002; Figure 3).

In tropical paleolatitudes, Middle and Upper Pennsylvanian (Desmoinesian-Virgilian, Moscovian-Gzhelian) shallow-water shelf and shelf-margin reef mounds consisted of bafflestones composed mostly of erect phylloid green and red algae (Wahlman 1988, 2002). In slightly deeper-water settings of adjacent upper slopes and intermound areas, communities of small calcisponges, bryozoans, and laminar red algae built small boundstone patch reefs (Toomey 1979; Schatzinger 1983). During the maximum glacioeustatic lowstands of the latest Pennsylvanian (Virgilian) and Early Permian (Wolfcampian), those two communities integrated and constructed upper slope to shelf-margin bafflestone-boundstone reef mounds composed of a framework of phylloid algae, calcisponges, and fenestrate and ramose branching bryozoans, which were encrusted by laminar red algae, *Tubiphytes*, fistuliporid bryozoans, and microbialites (Wahlman 1988, 2002; Figures 2 and 4). In some platform-margin buildups, siliceous heliosponges and specialized reefal brachiopods are locally

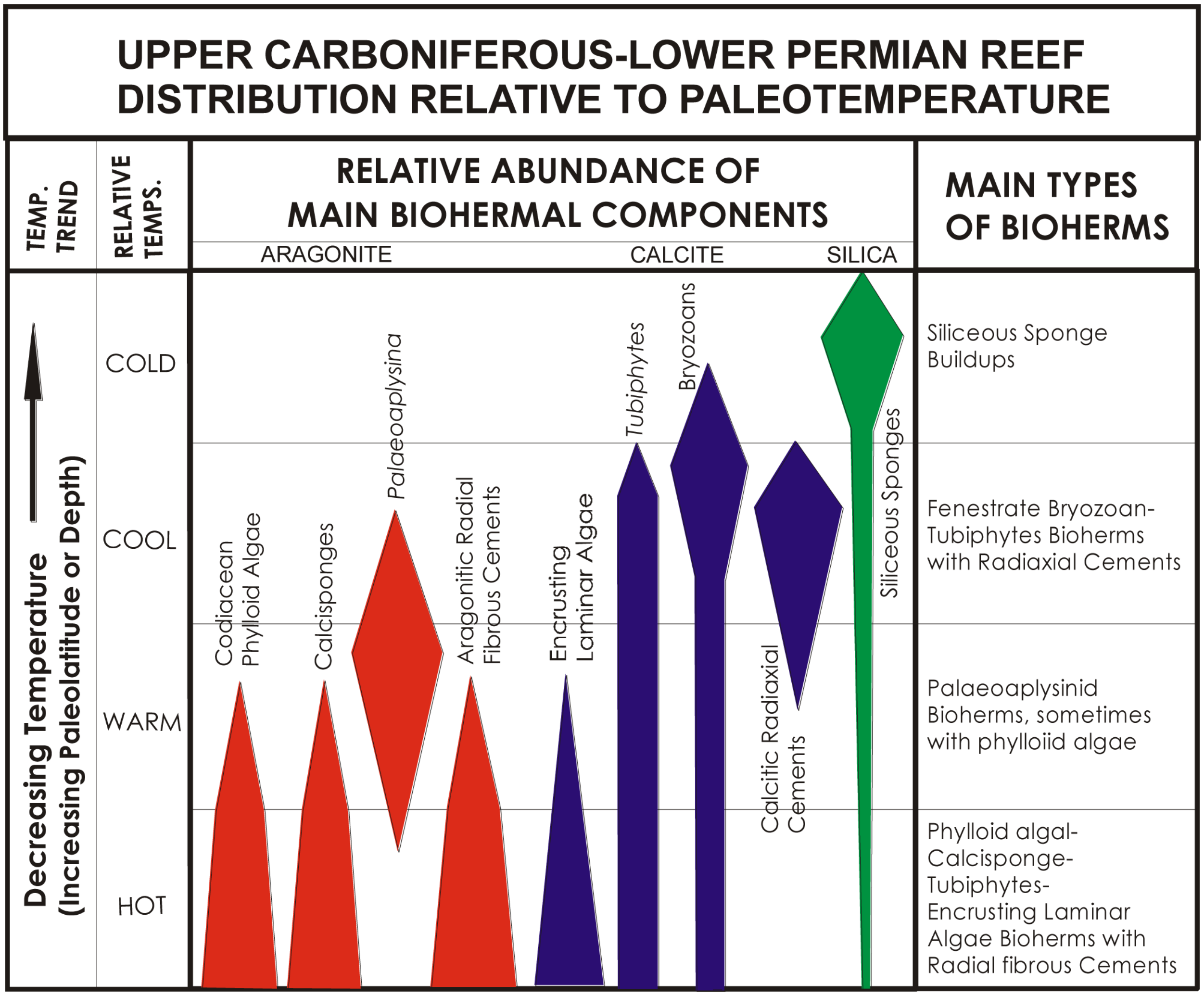

Figure 3. General distribution of major types of Upper Carboniferous (Pennsylvanian)-Lower Permian bioherm-building communities and their constituents relative to seawater temperature, which was controlled by paleolatitude, paleobathymetry, growth position relative to currents, or some combination of these factors. Note that the dominant warmer-water tropical biohermal components are aragonitic in composition, cooler-water buildup components are mainly Mg-calcite in composition, and cold-water buildup components are Mg-calcite and siliceous in composition. The aragonitic composition of the warmer-water components made them susceptible to meteoric dissolution during lowstands of the high-frequency glacioeustatic sealevel fluctuations, thereby creating abundant porosity and resultant petroleum reservoirs. Mg-calcite and siliceous buildups are relatively stable diagenetically and have a much lower likelihood of porosity and hydrocarbon reservoir formation. (Modified from Wahlman and Konovalova 2002).

common. Many uppermost Pennsylvanian and Lower Permian tropical reefs are also rich in syndepositional, originally-aragonitic, botryoidal radial fibrous cements. That circum-tropical, integrated reef-building community radiated and diversified through Permian time, growing in upper slope to shelf-margin settings and constructing characteristic distally-steepened platform margins (Wahlman and Tasker 2013). The reef-building community reached its acme of development in large Middle Permian reefs, such as the Capitan Reef of the Permian Basin in the southwestern USA (Figure 2).

At higher subtropical to low temperate paleolatitudes, Late Pennsylvanian-Early Permian shelf to shelf-margin reef mounds were constructed mainly by *Palaeoaplysina*, which was recently interpreted to be a relatively large phylloid red alga (Anderson and Beauchamp 2014), in association with varying proportions of smaller green phylloid algae (Beauchamp et al. 1989; Beauchamp 1992, 1993; Wahlman 2002; Figures 3 and 5). *Palaeoaplysina* buildups are characteristic of shallow-water platforms around the northern margin of the paleocontinent Pangea (NW North America, Canadian Arctic Archipelago, Spitsbergen and Barents Sea Region, and Timan-Pechora Basin and Ural Trough margin in northern Russia; Figure 1), and they form prospective petroleum reservoirs in the Timan-Pechora Basin of northern Russia and the Barents Sea (Stemmerik and Worsley 2005; Klimenko et al. 2011). In slightly deeper- and cooler-water slope settings, contemporaneous cool-water carbonate mudmounds were constructed mainly by calcitic fenestrate bryozoans, with varying amounts of *Tubiphytes*, crinoids, and radiaxial calcite cementstone (Beauchamp 1989a, 1989b, 1992, 1993; Beauchamp and Desrochers 1997; Blendinger et al. 1997; Wahlman and Konovalova 2002; Figures 3 and 5). Those two reef communities intermixed at intermediate depths, and the fenestrate bryozoan-*Tubiphytes*-radiaxial cementstone facies sometimes shallowed-upward into palaeoaplysinid reef mound facies (Wahlman and Konovalova 2002). In contemporaneous cold-water lower slope and basinal settings, siliceous sponges constructed mounds and banks, commonly with associated brachiopods and bryozoans (Beauchamp 1989a, 1989b; Beauchamp and Desrochers 1997).

2.2. Petroleum reservoir characterization

Most Pennsylvanian-Permian, tropical and subtropical, shallow-water reef mound buildups were composed largely of aragonitic organic and inorganic components (e.g., green phylloid algae, *Palaeoaplysina*, calcareous sponges, radial fibrous cements), whereas contemporaneous organic carbonate buildups in deeper- and/or cooler-water settings were dominated by Mg-calcite (e.g., bryozoans, *Tubiphytes*, radiaxial cements) and siliceous (sponges) constituents. Some of those cooler-water biotic elements also occur in warmer-water reefs, but they were greatly diluted by the more prolific growth of the tropical biota. The largely aragonitic composition of warmer-water reefs made them prone to subaerial meteoric dissolution during the high-frequency glacioeustatic sealevel fluctuations of the Late Paleozoic Icehouse period, and therefore they commonly form porous petroleum reservoirs (Wahlman 2001; Stemmerik and Larssen 1993; Stemmerik and Worsley 2005). Cooler-water buildups composed mostly of Mg-calcitic and siliceous elements are relatively stable diagenetically and are not generally prospective for porous petroleum reservoir development unless dolomitized and/or fractured.

3. Summary and Conclusions

During the Pennsylvanian-Permian Periods, there was a spectrum of reef communities that varied through both time and space. During the Pennsylvanian Period, calcareous phylloid algae became the dominant bioherm-builders in tropical shallow-water carbonate systems. In the Early Permian, the warm-water shelfal phylloid algal mound community integrated with upper slope small patch reef communities. The new Early Permian reef community was composed of mostly calcareous algae, calcisponges, *Tubiphytes*, and erect and encrusting bryozoans, with microbialite and submarine cementation often playing important roles in buildup construction. That pioneer Permian reef community diversified and radiated through Permian time (Figure 2). The Pennsylvanian-Permian tropical-subtropical shallow-water reef community was dominated by aragonitic components (calcareous algae, calcisponges, radial fibrous cements), which were susceptible to meteoric dissolution during high-frequency glacioeustatic sealevel

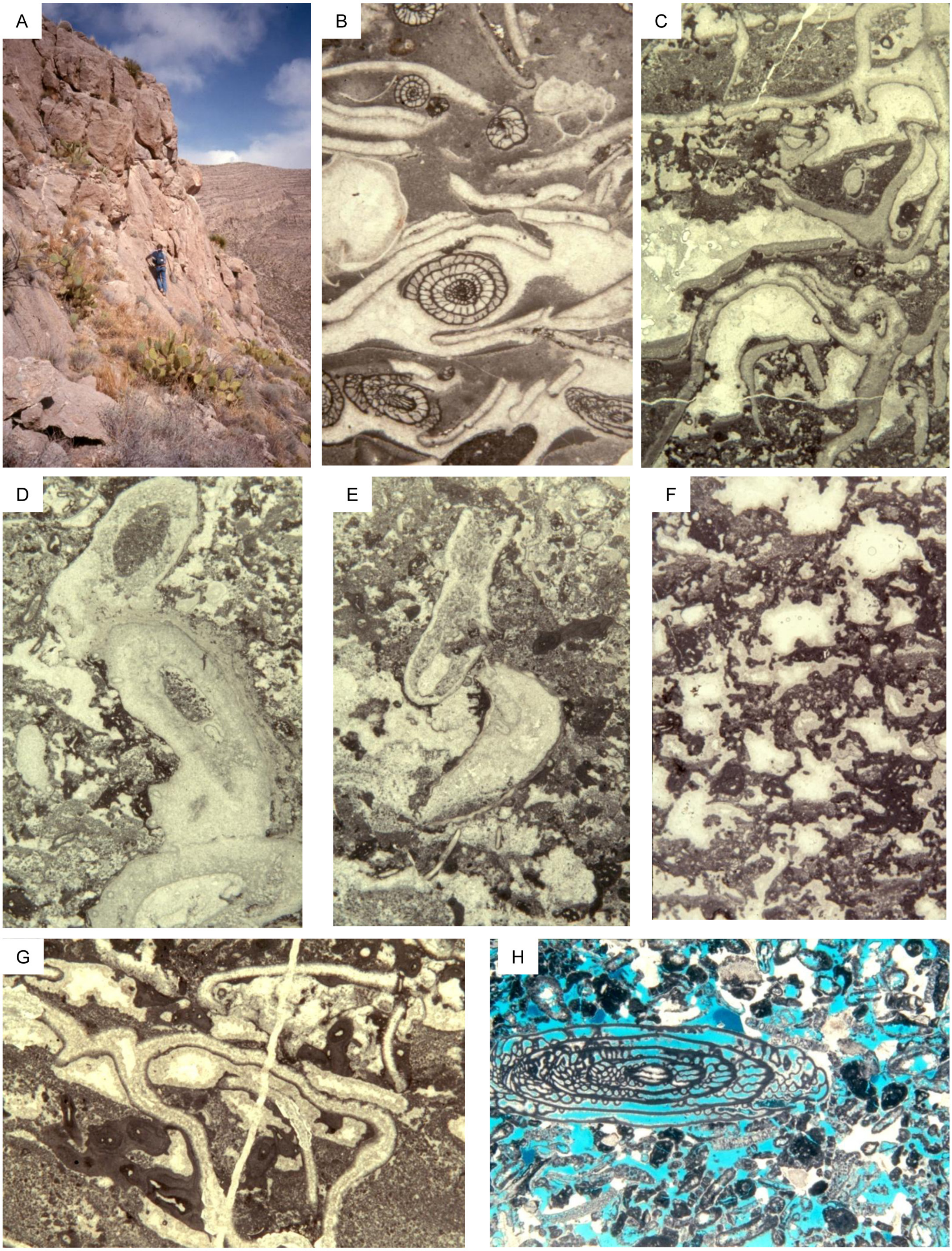
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Figure 4. (PREVIOUS PAGE) Warm-water tropical buildups. A) Outcrop photograph of lower Permian (Wolfcampian) phylloid algal mound in Hueco Mountains, west Texas (Douglas Tasker for scale). B) Photomicrograph of phylloid algal bafflestone from the mound shown in A, with cement-filled shelter cavities, fusulinid foraminifera, a brachiopod and gastropod. Figures C-H are all low-power (X4 to X8) photomicrographs of Lower Permian (Wolfcampian) reef facies in subsurface drill cores from the Permian Basin of west Texas. C) Phylloid algal bafflestone with cement-lined and cement-filled shelter cavities and common *Tubiphytes* encrustations. D) Calcisponges in *Tubiphytes* boundstone with fine peloidal cemented matrix. E) Calcisponge (upper left) and spinose productid brachiopod in growth position in *Tubiphytes* boundstone and fine peloidal cemented matrix; radial fibrous cements in underlying shelter cavity. F) *Tubiphytes* boundstone with anastomosing network of cavities that are lined by submarine isopachous cements. G) Phylloid algal bafflestone with *Tubiphytes* encrustations, shelter cavities lined by submarine isopachous cements, and fine peloidal cemented matrix. H) Bioclastic grainstone of crestal shoal overlying shelf-margin reef. Sample impregnated by blue epoxy to show >20% porosity, which is the result of lowstand subaerial exposure at the top of the sequence, and meteoric dissolution of the mostly aragonitic skeletal components. The large grain is a fusulinid larger foraminifer (*Schwagerina* sp.).

lowstands and so form important porous hydrocarbon reservoirs.

With increasing paleobathymetry and/or paleolatitude, seawater temperatures became cooler and the Pennsylvanian-Permian reef-building components gradually but markedly changed (Figure 3). Subtropical to low temperate shallow-water carbonate buildups were constructed by *Palaeoaplysina* (red phylloid algae), with associated green phylloid algae that decreased in abundance with increasing paleolatitude and/or depth. Adjacent deeper and cooler-water buildups were mainly calcitic mudmounds constructed by fenestrate bryozoans, with varying amounts of *Tubiphytes*, brachiopods, crinoids, and radiaxial cementstones. Such buildups sometimes shallowed-upward into *Palaeoaplysina* buildup facies. Contemporaneous deep-water and cold-water buildups graded into siliceous sponge mudmounds with varying amounts of associated brachiopods. The calcitic and siliceous buildups were relatively inert diagenetically, and have low potential for porous hydrocarbon reservoirs development.

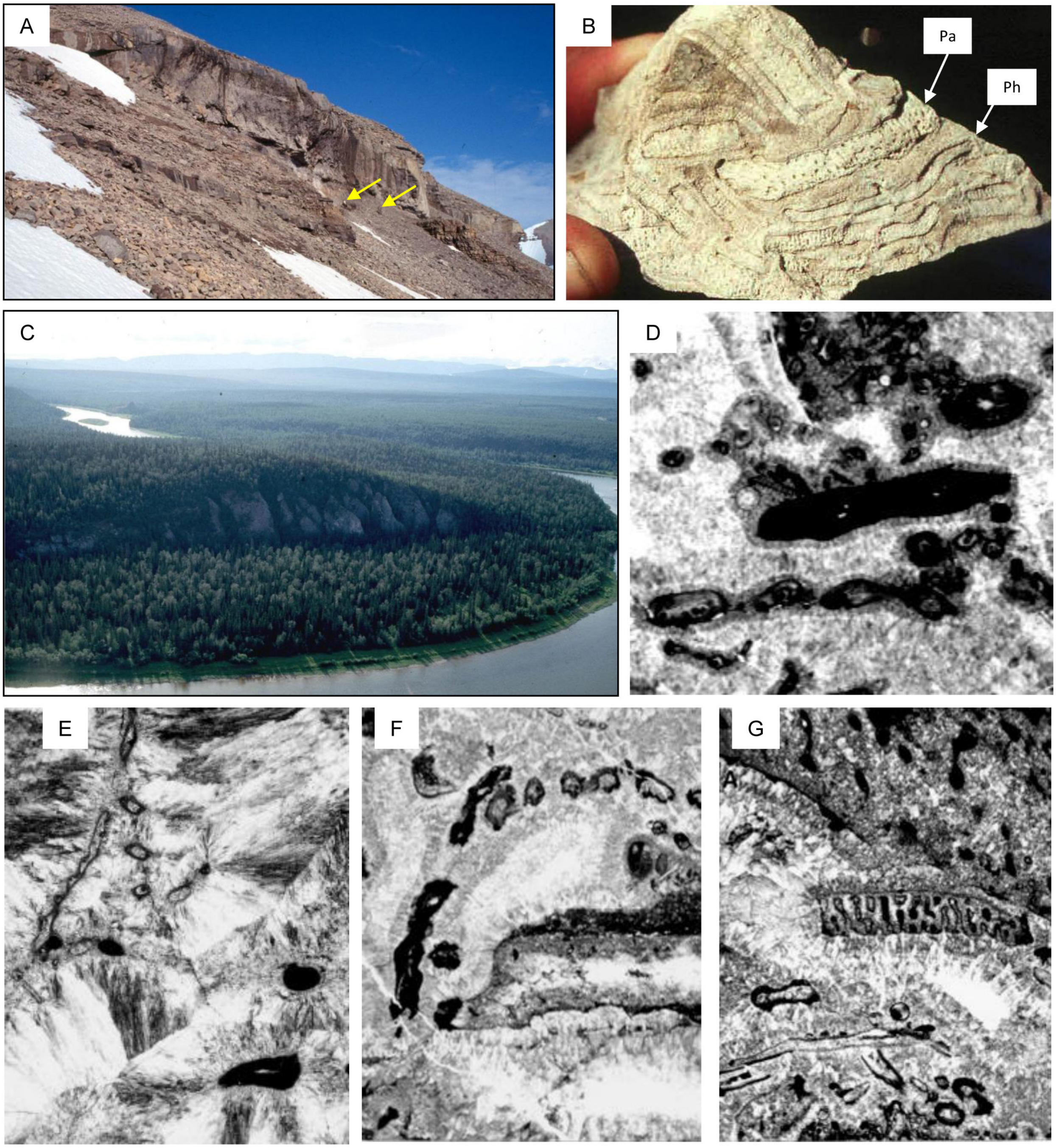
When working on carbonate rocks, and particularly fossil organic carbonate buildups, a geoscientist must always be aware of the age of the depositional sequence, the characteristics of the carbonate rocks and reef-building communities during that particular period of time, and the stratigraphic and paleoecologic responses of a study area's paleogeographic location and paleoclimatologic conditions.

4. References

Anderson, K. D., and B. Beauchamp. 2014. Paleobiology and paleoecology of *Palaeoaplysina* and *Eopalaeoaplysina* new genus in Arctic Canada. *Journal of Paleontology* 88: 1056–1071.

Babcock, J. A. 1977. Calcareous algae, organic boundstones, and the genesis of the Upper Capitan Limestone (Permian, Guadalupian), Guadalupe Mountains, west Texas and New Mexico. *In* M. E. Hileman and S. J. Mazzullo [eds.], Upper Guadalupian facies, Permian reef complex, Guadalupe Mountains, New Mexico and west Texas, 3–44. SEPM (Society of Economic Paleontologists and Mineralogists) Permian Basin Section Publication 77-16. Midland, Texas, USA.

Beauchamp, B. 1989a. Lower Permian (Artinskian) sponge-bryozoan buildups, southwestern Ellesmere Island, Canadian Arctic Archipelago. *In* H. H. J. Geldsetzer et al. [eds.], Reefs - Canada and Adjacent Areas, 575–584. Canadian Society of Petroleum Geologists Memoir 13. Calgary,



Alberta, Canada.

Beauchamp, B. 1989b. Lower Permian (Sakmarian) *Tubiphytes*-bryozoan buildup, southwestern Ellesmere Island, Canadian Arctic Archipelago. *In* H. H. J. Geldsetzer et al. [eds.], Reefs - Canada and Adjacent Areas, 585–589. Canadian Society of Petroleum Geologists Memoir 13. Calgary, Alberta, Canada.

Beauchamp, B. 1992. Carboniferous and Permian reefs of Sverdrup Basin, Canadian Arctic: an aid to Barents Sea exploration. *In* T. O. Vorren et al. [eds.], Arctic Geology and Petroleum Potential, 217–241. NPF (Norwegian Petroleum Society) Special Publication 2. Elsevier, Amsterdam, Netherlands.

Beauchamp, B. 1993. Carboniferous and Permian reefs of the Sverdrup Basin, Canadian Arctic Islands. *In* T. O. Vorren et

Figure 5. (PREVIOUS PAGE) Cool-water reef facies. A) Outcrop photograph of large (30-40 m thick) *Palaeoaplysina*-phylloid algal buildup, Boltonbreen, Spitsbergen, Arctic Norway (arrows point to people for scale). B) Small outcrop specimen of *Palaeoaplysina*-phylloid algal bafflestone from top of Kozhim reef, Timan-Pechora Basin, subpolar pre-Ural Mountains, northern Russia. Note that *Palaeoaplysina* plates (Pa) are generally larger than associated phylloid green algal plates (Ph). (Photo about 6 cm wide). C) Oblique aerial photograph taken from a helicopter of the Upper Carboniferous-Lower Permian (Kasimovian-Sakmarian) Kozhim reef exposed on a bend of the Kozhim River, subpolar- pre-Ural Mountains, northern Russia. Figures D-G are low power photomicrographs (X4 to X10) with D, E, and F under plane light, and E under cross-polarized light. D) Photomicrographs of deep- and cool-water fenestrate bryozoan-radiaxial cementstone facies of the Kozhim reef. E) Same facies as D under cross-polarized light to show the characteristic radiaxial calcite cement extinction pattern. F) Same facies as D-E, but from higher in Kozhim reef, with a recrystallized *Palaeoaplysina* plate. G) Large (top) and smaller *Palaeoaplysina* plates with microstructure preserved, and fenestrate bryozoan-*Tubiphytes*-radiaxial cementstone below.

al. [eds.], Pangea: Paleoclimate, Tectonics, and Sedimentation during Accretion, Zenith and Breakup of a Supercontinent, 229–246. Geological Society of America Special Paper 228. Boulder, Colorado, USA.

Beauchamp, B., G. R. Davies, and W. W. Nassichuk. 1989. Upper Carboniferous to Lower Permian *Palaeoaplysina*-phylloid algal buildups, Canadian Arctic Archipelago. *In* H. H. J. Geldsetzer et al. [eds.], Reefs - Canada and Adjacent Areas, 590–599. Canadian Society of Petroleum Geologists Memoir 13. Calgary, Alberta, Canada.

Beauchamp, B., and A. Desrochers. 1997. Permian warm- to very cold-water carbonates and chert in the Sverdrup Basin-Barents Sea area, northwestern Pangea. *In* N. P. James and J. A. D. Clarke [eds.], Cool-Water Carbonates, 327–347. SEPM (Society for Sedimentary Geology) Special Publication 56. Tulsa, Oklahoma, USA.

Blendinger, W., B. Bowlin, F. R. Zijp, G. Darke, and M. Ekroll. 1997. Carbonate buildup flank deposits: an example from the Permian (Barents Sea, northern Norway) challenges classical facies models. *Sedimentary Geology* 112: 89–103.

Golonka, J. 2002. Plate tectonic maps of the Phanerozoic, *In* W. Kiessling, E. Flugel, and J. Golonka [eds.], Phanerozoic Reef Patterns, 21–75. SEPM (Society for Sedimentary Geology) Special Publication 72. Tulsa, Oklahoma, USA.

James, N. P. 1983. Reef environment. *In* P. A. Scholle, D. G. Bebout, and C. H. Moore [eds.], Carbonate Depositional Environments, 345–440. American Association of Petroleum Geologists Memoir 33. Tulsa, Oklahoma, USA.

James, N. P., and P-A. Bourque. 1992. Reefs and mounds. *In* R. G. Walker and N. P. James [eds.], Facies models, response to sea level change, 323–348. Geological Association of Canada. St. John's, Newfoundland, Canada.

Kerans, C., and S. W. Tinker. 1997. Sequence stratigraphy and characterization of carbonate reservoirs, 1–130. SEPM (Society for Sedimentary Geology) Short Course No. 40. Tulsa, Oklahoma, USA.

Kiessling, W., E. Flugel, and J. Golonka [eds.]. 2002. Phanerozoic Reef Patterns. SEPM (Society of Sedimentary Geology) Special Publication 72. Tulsa, Oklahoma, USA.

Klimenko, S. S., L. A. Anishenko, and A. I. Antoshkina. 2011. The Timan-Pechora sedimentary basin: Paleozoic reef formations and petroleum systems. *In* A. M. Spencer, A. F. Embry, D. L. Gautier, A. V Stoupakova, and K. Sorensen [eds.], Arctic Petroleum Geology, 223–236. Geological Society Memoir 35. London, England.

Newell, N. D., J. K. Rigby, A. G. Fischer, A. J. Whiteman, J. E. Hickox, and J. S. Bradley. 1953. The Permian reef complex of the Guadalupe Mountains region, Texas and New Mexico. W.H. Freeman and Company, San Francisco, California, USA.

RANKEY, E. C., S. L. BACHTEL, AND J. KAUFMAN. 1999. Controls on stratigraphic architecture of Icehouse mixed carbonate-siliciclastic systems: a case study from the Holder Formation (Pennsylvanian, Virgilian), Sacramento Mountains, New Mexico. *In* P. M. Harris, A. H. Saller, and J. A. Simo [eds.], Advances in carbonate sequence stratigraphy: Application to reservoirs, outcrops, and models, 127–150. SEPM (Society for Sedimentary Geology) Special Publication 63. Tulsa, Oklahoma, USA.

READ, J. F., C. KERANS, AND L. J. WEBER. 1995. Milankovitch sea level changes, cycles and reservoirs on carbonate platforms in greenhouse and ice-house worlds, 1–102. SEPM (Society of Economic Paleontologists and Mineralogists) Short Course Notes 35. Tulsa, Oklahoma, USA.

SALLER, A. H., P. M. HARRIS, B. L. KIRKLAND, AND S. J. MAZZULLO (eds.). 1999. Geologic framework of the Capitan Reef. SEPM (Society for Sedimentary Geology) Special Publication 65. Tulsa, Oklahoma, USA.

SCHATZINGER, R. A. 1983. Phylloid algal and sponge-bryozoan mound-to-basin transition – a Late Paleozoic facies tract from Kelly-Snyder Field, west Texas. *In* P. M. Harris [ed.], Carbonate Buildups - a core workshop, 244–303. SEPM (Society of Economic Paleontologists and Mineralogists) Core Workshop 4. Tulsa, Oklahoma, USA.

STEMMERIK, L., AND G. B. LARSSEN. 1993. Diagenesis and porosity evolution of Lower Permian *Palaeoaplysina* buildups, Bjornoya, Barents Sea: an example of diagenetic response to high frequency sea level fluctuations in an arid climate, *In* A. D. Horbury and A. G. Robinson [eds.], Diagenesis and Basin Development, 199–211. American Association of Petroleum Geologists, Studies in Geology 36. Tulsa, Oklahoma, USA.

STEMMERIK, L., AND D. WORSLEY. 2005. 30 years on Arctic Upper Paleozoic stratigraphy, depositional evolution and hydrocarbon prospectivity. *Norwegian Journal of Geology* 85: 151–168.

TOOMEY, D. F. 1979. Role of archaeolithophyllid algae within a late Carboniferous algal-sponge community, southwestern United States. *Bulletin Centres Recherches Exploration-Production Elf-Aquitaine* 3: 843–853.

WAHLMAN, G. P. 1988. Subsurface Wolfcampian (Lower Permian) shelf-margin reefs in the Permian Basin of west Texas and southeastern New Mexico. *In* W. P. Morgan and J. A. Babcock [eds.], The Permian of the Midcontinent, 177–204. SEPM (Society of Economic Paleontologists and Mineralogists) Midcontinent Section Special Publication 1. Tulsa, Oklahoma, USA.

WAHLMAN, G. P. 2001. Pennsylvanian-Lower Permian mounds and reefs in the Permian Basin (West Texas-New Mexico): composition, evolution, distribution, and reservoir characteristics. *In* J. J. Viveiros and S. M. Ingram [eds.], The Permian Basin: Microns to Satellites, Looking for Oil and Gas at all Scales, 57–64. West Texas Geological Society Publication 01-110. Midland, Texas, USA.

WAHLMAN, G. P. 2002. Upper Carboniferous-Lower Permian (Bashkirian-Kungurian) mounds and reefs. *In* W. Kiessling, E. Flugel, and J. Golonka [eds.], Phanerozoic Reef Patterns, 271–338. SEPM (Society for Sedimentary Geology) Special Publication 72. Tulsa, Oklahoma, USA.

WAHLMAN, G. P., AND M. V. KONOVALOVA. 2002. Upper Carboniferous-Lower Permian Kozhim carbonate bank, Subpolar Ural Mountains, Russia: outcrop analog for some Timan Pechora Basin Reservoirs. *In* W. A. Zempolich, and H. E. Cook [eds.], Carbonate Reservoirs and Field Analogs of the CIS, 223–245. SEPM (Society for Sedimentary Geology) Special Publication 74. Tulsa, Oklahoma, USA.

Wahlman, G. P., and D. R. Tasker. 2013. Lower Permian (Wolfcampian) shelf-margin and slope facies, Central Basin Platform and Hueco Mountains, Permian Basin, West Texas, USA. *In* K. Verwer, T. E. Playton, and P. M. Harris [eds.], Deposits, architecture, and controls of carbonate margin, slope, and basinal settings, 305–333. SEPM (Society for Sedimentary Geology) Special Publication 105. Tulsa, Oklahoma, USA.

West, R. R. 1988. Temporal changes in Carboniferous reef mound communities. *Palaios* 3: 152–169.