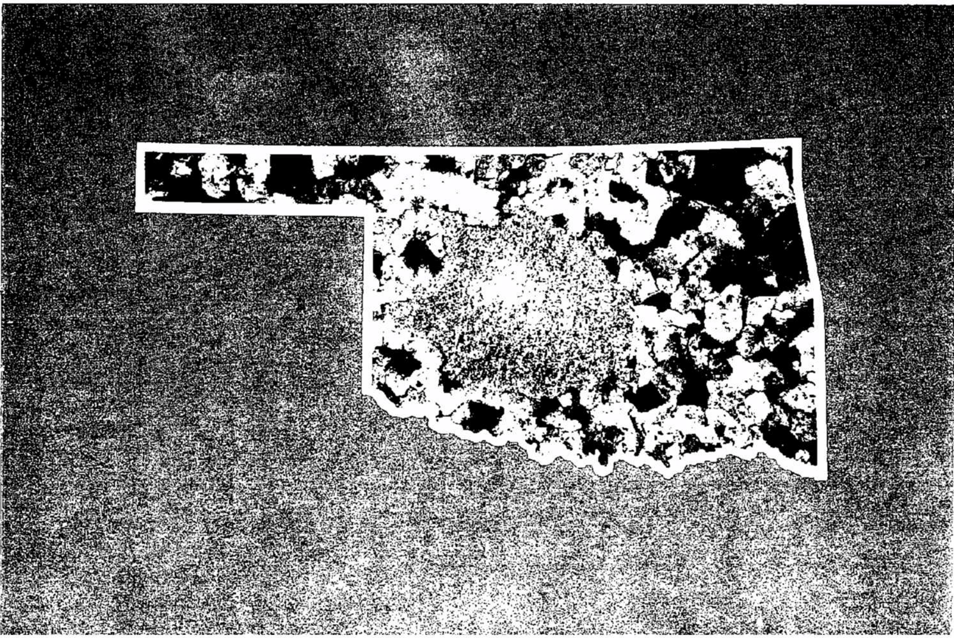
# OKLAHOMA GEOLOGY NOTES



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## *Cover Picture*

### Dolomitization in the Foraker Formation

The cover picture is a photomicrograph of a thin section (x36, plain light) of a sample taken from the Foraker Formation (Permian) along the south section line of sec. 23, T. 20 N., R. 5 E., Pawnee County, north-central Oklahoma. The stratigraphic position of the sample is 17 feet above the base of the Long Creek Member.

The slide illustrates the typical occurrence of dolomite in this formation. The dolomite grains are commonly euhedral and subhedral. The large crinoid fragment shown in the photograph displays an irregular boundary with a halo of dolomite grains. The grain shapes and the mode of occurrence about the crinoid fragment indicate that the dolomite is secondary, resulting from the alteration of calcium carbonate. Although many samples of dolomitic rock from the Foraker Formation have been examined, no evidence of primary dolomite has been observed.

—*Ataolah Mogharabi*

# New Isochilinid Ostracode from the West Spring Creek Formation (Arbuckle Group) of Oklahoma

Wilgus B. Creath*

## INTRODUCTION

Two species of *Isochilina* of similar morphology occur on opposite sides of the Arbuckle-Simpson lithologic boundary in southern Oklahoma. The Arbuckle species, *Isochilina kamara,* is new; the Simpson species, *Eoleperditia*? *obesiporosa* Harris, 1957, has been reexamined and is assigned to the genus *Isochilina.* Both are similar to *Isochilina seelyi* (Whitfield, 1889). Specimens of both *I. kamara* and *I. obesiporosa* have been collected from two localities: the West Spring Creek locality (SW¼ sec. 31, T. 1 S., R. 1 W., along West Spring Creek, Murray County) and the U. S. Highway 77 locality (NE¼ sec. 19, T. 2 S., R. 2 E., on the west side of U. S. Highway 77, Carter County). *I. kamara* occurs in the West Creek Formation (upper part of the Arbuckle Group), *I. obesiporosa* in the Joins Formation (lower part of the Simpson Group).

The specimens illustrated herein are in the collections of the Harvard Museum of Comparative Zoology (MCZ), the U. S. National Museum (USNM), the American Museum of Natural History (AMNH), and the Pan American Petroleum Corporation (Pan American).

R. W. Harris critically read the manuscript and J. R. Derby aided in collecting and preparing the specimens. Examination of the holotype of *Eoleperditia*? *obesiporosa* was made possible through the cooperation of H. B. Whittington, Harvard Museum of Comparative Zoology, and J. Berdan of the U. S. Geological Survey.

## SYSTEMATIC DESCRIPTION

Subclass Ostracoda Latrielle, 1806
Order Leperditicopida Scott, 1961
Family Isochilinidae Swartz, 1949

### Genus *Isochilina* Jones, 1858

#### *Isochilina kamara* Creath, new species

Plate I, figures 1, 2, 9, 10

*Description.*—The carapace is subequivalved, amplete to slightly postplete, subovate in lateral outline, with a straight dorsum and convex venter. Cardinal processes are well developed. A broad, flattened peripheral border is developed about the anterior and posterior margins, absent midventrally. The eyespot is pronounced. A smooth, elliptical muscle scar is observable posteroventral to the eyespot; a shallow sulcus

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appears above the muscle scar. The ventral profile is evenly convex. The central portion of the carapace is covered with coarse (0.1 mm) punctae; punctae absent in cardinal areas, about all margins, in sulcus, and upon muscle scar. The anterodorsal slope is fairly straight.

The holotype (USNM 156272) is a right valve, 4.30 mm long and 2.87 mm high, from 56.5 feet below the top of the West Spring Creek Formation (Arbuckle Group) at the U. S. Highway 77 locality.

*Remarks.—Isochilina kamara* is quite similar to, and is probably the precursor of, *I. obesiporosa*. The major difference is in the ventral profile; *I. kamara* consistently displays an evenly convex ventral profile, whereas that of *I. obesiporosa* is consistently asymmetrical. Also, *I. kamara* lacks the distinct posterodorsal swelling of *I. obesiporosa;* however, this swelling is a variable feature and is of doubtful value in specific differentiation. Large specimens of *I. obesiporosa* may have a more distinct eye tubercle but the prominence of this feature appears to be a function of the size and state of preservation of the individual and has little utility in differentiating the two species.

*I. kamara* and *I. obesiporosa* are quite similar to *I. seelyi* (Whitfield, 1889), (pl. I, figs. 11, 12). All three species exhibit "granules" in the punctae; however, the punctae of *I. seelyi* are slightly smaller (0.05-0.07 mm), more closely spaced, and more generally distributed

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**Explanation of Plate I**

(All photographs x10)

**Figures 1, 2.** Isochilina kamara, **new species, holotype USNM 156272; a right valve from 56.5 feet below top of West Spring Creek Formation at U. S. Highway 77 locality.**
**1. Right lateral view.**
**2. Ventral view.**

**Figures 3, 4.** Isochilina obesiporosa **(Harris), Pan American 2733-53, specimen 54; a right valve from 18 feet above base of Joins Formation at West Spring Creek locality.**
**3. Right lateral view.**
**4. Ventral view.**

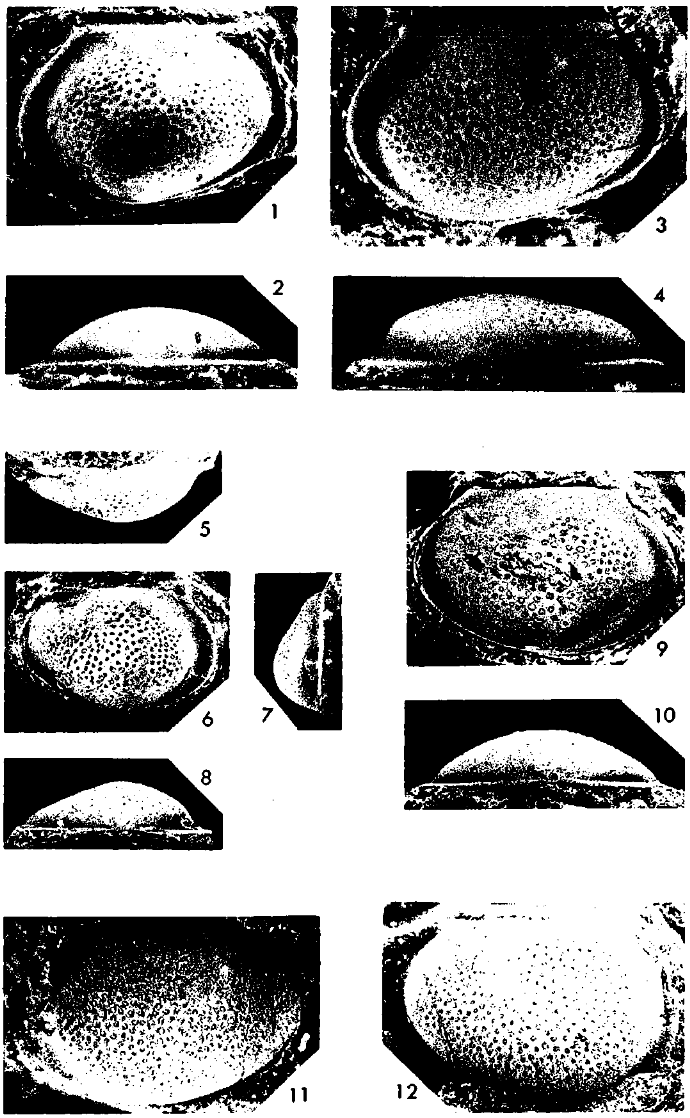
**Figures 5-8.** Isochilina obesiporosa **(Harris), holotype MCZ 4497; a left valve from 42 feet above base of Joins Formation at U. S. Highway 77 locality.**
**5. Dorsal view.**
**6. Left lateral view.**
**7. Posterior end.**
**8. Ventral view.**

**Figures 9, 10.** Isochilina kamara, **new species, Pan American 2733-12, specimen 51; a left valve from 38 feet below top of West Spring Creek Formation at West Spring Creek locality.**
**9. Left lateral view.**
**10. Ventral view.**

**Figure 11.** Isochilina seelyi **(Whitfield), holotype AMNH 393; right valve illustrated by Whitfield (1889, pl. 13, fig. 6).**

**Figure 12.** Isochilina seelyi **(Whitfield); a left valve from Whitfield type collection.**

**Plate I**



over the surface of the valve. *I. seelyi* lacks the posterodorsal inflation of *I. obesiporosa*. The eye tubercle of *I. seelyi* is faint and scarcely visible; those of *I. kamara* and *I. obesiporosa* are more pronounced. *I. kamara* and *I. obesiporosa* have a shallow sulcus; *I. seelyi* has none.

### *Isochilina obesiporosa* (Harris, 1957), new combination

Plate I, figs. 3-8

**Eoleperditia? obesiporosa** Harris, 1957, Okla. Geol. Survey, Bull. 75, p. 133, pl. 1, figs. 7a, 7b.

*Description.*—The description, as published by Harris (1957, p. 133-134), is emended as follows:

The carapace is subequivalved, amplete to slightly postplete, subovate in lateral outline, with straight dorsum and convex venter. Cardinal processes are well developed. A broad, flattened peripheral border is developed about anterior and posterior margins, absent midventrally. The eyespot is pronounced. A smooth elliptical muscle scar is situated posteroventral to the eyespot. A shallow sulcus lies above the muscle scar. Posterodorsal inflation is developed to varying degrees. Specimens consistently exhibit an asymmetrical ventral profile, with a long anterior slope and a shorter, steeper posterior slope. The slope between the flattened posterior border and the posteromedian portion of the carapace is quite steep, almost vertical in some specimens. The central portion of the carapace is covered with coarse (0.1 mm) punctae; punctae are absent in the cardinal areas, about all margins, in the sulcus, and upon the muscle scar.

The holotype (MCZ 4497) is a left valve from 42 feet above the base of the Joins Formation (Simpson Group) at the U. S. Highway 77 locality.

*Remarks.*—The removal of additional rock matrix from Harris' holotype (MCZ 4497) and the examination of additional specimens from the two aforementioned localities, have yielded evidence that this ostracode should be assigned to the genus *Isochilina*. The most pronounced generic characteristic of *Eoleperditia* is the marked overlap of the right valve beyond the left valve along the ventral margin, with accompanying pits or "stops" along the ventral margin of the larger right valve. *Isochilina obesiporosa* is subequivalved and lacks the ventral pits. The fact that it is subequivalved precludes its being included in the Leperditiidae. Also, *Eoleperditia* is nonsulcate, whereas *I. obesiporosa* possesses a shallow sulcus. The genus *Isochilina* is characterized by subequal valves with a flattened border that extends along the free margin but is weak or absent midventrally; sulcus and eye tubercle may range in development from faint to pronounced.

#### References Cited


**Harris, R. W.**, 1957, Ostracoda of the Simpson Group: Okla. Geol. Survey, Bull. 75, 333 p., 19 figs., 10 pls., 5 charts.

**Whitfield, R. P.**, 1889, Observations on some imperfectly known fossils from the Calciferous sandrock of Lake Champlain, and descriptions of several new forms: Amer. Museum Nat. History, Bull., vol. 2, no. 2, p. 41-63.

# Advanced Crude-Oil Recovery Techniques In Oklahoma*

Lee A. Keeling†

## INTRODUCTION

Since the end of World War II, the oil industry has directed its efforts toward increasing ultimate recovery from known oil-bearing reservoirs. The cost of finding new oil is increasing; consequently, development of new recovery techniques becomes more important each day. Oil recoveries, utilizing conventional production methods, range from 5 to 50 percent of the oil in place. Obviously, appreciable quantities of oil remain to be recovered by new recovery techniques. Routine waterflooding, recycling, and gas injection are considered conventional recovery techniques and do not fall in the category of advanced recovery methods.

The purpose of this paper is to review modern recovery methods that have been tested by operators in Oklahoma. Most operators, both large and small, are directing more of their efforts towards increasing profits by producing additional oil from existing producing properties. As a result, more and more attention is being devoted to the investigation and application of these methods. The number of advanced recovery projects initiated in Oklahoma since 1948 is summarized in table I; individual projects are listed in table II.

Detailed information pertaining to the success or failure of most of these projects has been withheld from industry. This situation pertains particularly to the Midcontinent region. Because of the secrecy surrounding most of these projects and the confidential nature of our work, the contents of this paper are limited by the secrecy policies of the producing companies, and only general observations and conclusions can be given.

Although a certain amount of secrecy is necessary in the competition of acreage and in the protection of patent rights, the reluctance of industry to discuss mutual technical and practical problems actually tends to deny us that which we are trying to achieve, the production of more oil at lower costs. The exchange of technical information among operators can turn unprofitable ventures into profitable ones by, among other things, the elimination of duplication of effort.

## ADVANCED RECOVERY METHODS

A review of various technical-society transactions and articles published in the trade journals over the past few years would lead

* This paper is a modified abridgment of one presented before the Joint Committee Session of the Interstate Oil Compact Commission at Tulsa, June 20, 1966. The original paper (to which the reader is referred for additional information on the Midcontinent area) was published in the Interstate Oil Compact Commission Committee Bulletin (Keeling, 1966).

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one to believe that many new techniques and recovery processes are now being tested throughout the world; however, most of the new techniques and processes fall into one of three basic categories. These are (1) thermal recovery, (2) miscible-phase displacement, and (3) chemical additives in waterflooding.

### *Thermal Recovery*

Thermal recovery is currently receiving the major emphasis, as evidenced by the number of projects that have been developed over the past few years and also by the attention it is receiving in literature. In its simplest definition, thermal recovery is the application of heat to an oil reservoir. Thermal recovery is generally considered to have its widest application in reservoirs containing low-gravity, high-viscosity crudes.

The several variations of the thermal process include in-situ combustion, steam stimulation (often referred to as "steam soak" or "huff and puff"), direct steam drive, and hot-water flooding.

*In-situ combustion.*—In the in-situ process the burning of a portion of the reservoir oil provides the heat and the driving forces which push the remaining oil toward the producing wells. During the last five years, in-situ combustion has gone from the embryo to the young adult stages in commercial field application. Without argument, California holds the spotlight position because its reservoirs possess practically all the desired parameters, such as large amounts of oil per acre-foot in place (1,500 to 2,000 barrels per acre-foot), low-gravity but not too viscous crude (15 to 20 degrees API and 500 to 1,000 centipoises), mobility under natural conditions, shallow depths (most of the viscous crude is less than 3,000 feet deep), and high permeabilities (usually more than one darcy).

*Steam stimulation.*—The second and most widely applied thermal method in the United States at this time is steam stimulation. In this process, steam is injected into a producing well for a predetermined length of time after which the well is returned to productive status. The effect of well-bore clean-up is just as important as the effect of viscosity reduction and thermal swelling.

*Steam drive.*—The third thermal-recovery method is a steam drive in which steam is injected into the reservoir in essentially the same manner as is water in a conventional waterflood. Interest in this process is increasing as the limitations of steam-stimulation techniques become apparent.

*In-situ combustion-steam stimulation combination.*—A combination also receiving some attention is the in-situ combustion-steam stimulation, in which the combustion process provides the reservoir drive and oil bank while the steam stimulates the crude oil in the vicinity of the producing well. Various combinations of this type will be attempted in the future.

*Hot-water flooding.*—Hot-water flooding is simply the systematic injection of heated water into an oil reservoir. The process has not been tested extensively in this area; however, certain other areas have reservoir conditions and fluid characteristics that favor the injection of hot water.

### *Miscible-Phase Displacement*

*LPG and enriched-gas drive.*—Miscible-phase displacement involves the use of liquefied petroleum gas in the form of an LPG slug or enriched gas driven by dry gas and water. This process has been thoroughly field tested and proved to be commercially feasible in some areas where LPG can be obtained in large quantities at prices one-third or less the price of the crude oil to be recovered. It appears to be most applicable in thin sand reservoirs containing high-gravity crude with sufficient reservoir pressure to insure miscibility. Oil recoveries in the magnitude of 50 percent of the original oil in place appear possible by the use of the LPG or enriched-gas drive. However, at the present time, the LPG demand and prices are high; consequently, practical use of this process in the immediate future does not appear likely.

*High-pressure vaporization.*—High-pressure vaporization is a form of miscible-phase displacement which may have greater application in future years as deeper reservoirs are discovered. This process requires high-gravity volatile crudes and reservoir pressures of approximately 5,000 psi.

*Carbon dioxide.*—In a search for a cheap miscible agent, it was found that carbon dioxide was miscible, either totally or partially, in some crudes, and the use of carbon dioxide as a miscible-phase agent has been tried in several instances in the field. However, not enough data are available to consider this process tested and proved. Of prime concern in the use of this process is the availability of inexpensive carbon dioxide.

*Tertiary application.*—Research is also being conducted in the application of miscible-phase displacement to tertiary recovery from previously waterflooded reservoirs. It may be possible to inject lean gas and water at pressures of 2,000 to 3,000 psi into reservoirs having sufficient residual oil in the flooded portion to obtain miscibility with residual oil as the gas moves through the flooded zones.

### *Chemical Additives for Waterflooding*

Recovery techniques employing chemical additives have been attempted for several years. Most of the attempts have been confined to waterflood projects where detergents and other chemicals have been used in an effort to improve injectivity and ultimate oil recovery. Chemical additives are being investigated which may be effective in improving the profile of the flood bank, particularly in reservoirs containing moderately viscous crudes, as well as reducing the residual-oil saturation after waterflooding.

## OKLAHOMA PROJECTS

Advanced recovery methods are being tested in primary-, secondary- and tertiary-type operations. Past and present projects involving these methods include both experimental and operational projects designed for commercial exploitation. The lack of published data makes it difficult to distinguish between the two categories. Early in-situ projects were probably developed in the Midcontinent area because most of the companies held leases producing from zones at shallow depths which were relatively close to the various research laboratories. Most projects developed during the past two years have been an outgrowth of work performed in other areas. Thermal work done in California provided the impetus for testing steam techniques in the Midcontinent area.

Projects have been confined to southeastern Kansas, southwestern Missouri, and Oklahoma because substantial volumes of oil not recoverable by conventional methods occur in these areas at relatively shallow depths. Of the fifty-five projects known to have been undertaken in the Midcontinent area (Keeling, 1966), thirty-two were in Oklahoma (tables I, II). As of June 1966, eleven Oklahoma projects were still active.

Applicable reservoirs in Oklahoma are primarily sandstones of Pennsylvanian age, although a few projects in southern Oklahoma have been conducted in Permian sandstones. Thermal projects have been developed in reservoirs ranging from 100 to 3,000 feet, whereas miscible-phase-displacement projects are at much greater depths. Sand thicknesses range considerably, from a few feet to as much as 100 feet; however, most sands are thin in comparison to the massive zones of California.

*In-situ combustion.*—The first reported in-situ project in the Midcontinent area, and also the United States, was initiated in the Delaware-Childers field in Nowata County, Oklahoma, in 1948, when Sinclair conducted a small in-situ-combustion project on its Tanner

(text continues on page 254)

TABLE I.—ADVANCED RECOVERY PROJECTS INITIATED IN OKLAHOMA, 1948-1965

(**Boldface number** is number of projects active as of 1966)

| YEAR | IN SITU | STEAM | HOT WATER | MISCIBLE | TOTAL |
|---|---|---|---|---|---|
| 1948 | 1 | | | | 1 |
| 1952 | 1 | | | | 1 |
| 1953 | 1 | | | 1 | 2 |
| 1957 | | | | 1 | 1 |
| 1958 | | | | 1 | 1 |
| 1959 | | | | 2 | 2 |
| 1960 | 3 (1) | | | | 3 ( 1) |
| 1961 | 1 (1) | | | 3 (3) | 4 ( 4) |
| 1962 | 1 | 1 | | 1 | 3 |
| 1963 | 1 | | 1 (1) | | 2 ( 1) |
| 1964 | 2 (1) | 3 (1) | | | 5 ( 2) |
| 1965 | 2 (2) | 4 | | 1 (1) | 7 ( 3) |
| Total | 13 (5) | 8 (1) | 1 (1) | 10 (4) | 32 (11) |

**Table II.—Advanced Recovery Projects in Oklahoma**

(Information available as of June 1966; † = active project; other footnotes on page 253)

| Field | Location Sec. | T. | R. | Operator, Project Name, Year Initiated | Method* | Stratigraphic Unit | Depth (ft) | Thickness (ft) | Oil Gravity (°API) |
|---|---|---|---|---|---|---|---|---|---|
| **Beckham County** | | | | | | | | | |
| Elk City | 17 | 10N | 20W | Shell, "M" West, 1959[1] | ME | Hoxbar "M" | 9600-9800 | | 50 |
| Elk City | 25 | 10N | 20W | Shell, $P_1$ Propane Flood, 1958[1] | MG | Hoxbar $P_1$ | 10300 | 15 | 48 |
| **Carter County** | | | | | | | | | |
| Homestead | 29, 30, 32 | 3S | 1 E | Magness, 1965[6] | SS | Hoxbar | 400-800 | | 14 |
| Tatums | 23 | 1S | 3W | Mobil, Tatums Unit, 1965[6] | SS | Tatums | 2500 | | 24 |
| Sho-Vel-Tum | 9, 16 | 2S | 2W | Shell, Des Moines Unit-Hefner Lse. Proj., 1964† | SD | Hoxbar | 800-2000 | | 14-16 |
| Sho-Vel-Tum | 15, 16, 21, 22 | 2S | 2W | Mobil, Cox Penn. Sand Unit, 1961† | IS | Fourth Deese | 1000-2000 | | 16 (22 |
| Hewitt | 2, 3 | 4S | 2W | Vernon Price, 1965† | IS | 100-foot sand | 100 | 30 | [7] |
| **Cleveland County** | | | | | | | | | |
| Short Junction | | 10N | 4W | Continental, Unit, 1962[1] | MG | Hunton | 8000 | | |
| **Cotton County** | | | | | | | | | |
| Walters | 2 | 2S | 10W | Pan American, 1962[1] | IS | Priddy or Walters | 2000 | 20 | 37 |

(table continued on next page)

TABLE II (cont.)

| FIELD | SEC | LOCATION T. | R. | OPERATOR, PROJECT NAME, YEAR INITIATED | METHOD* | STRATIGRAPHIC UNIT | DEPTH (FT) | THICKNESS (FT) | OIL GRAVITY (°API) |
|---|---|---|---|---|---|---|---|---|---|
| **Creek County** | | | | | | | | | |
| Red Bank | 10 | 16N | 8 E | Sunray-DX, 1965† | IS | Dutcher | 3300 | | 20 |
| Bowden | 6 | 18N | 11 E | Home Stake Prod., Martha Bigpond 61-0, 1964[4] | SS | Red Fork | 1646 | | 32 |
| Bowden | 12 | 18N | 11 E | Home Stake Prod., Sallie Lee 14-W, 1964[4] | SS | Bartlesville | 1753 | | 32 |
| **Garvin County** | | | | | | | | | |
| Butterly | 14 | 1N | 1 E | Continental, 1963† | HW | Pontotoc | 1500 | 16-50 | 30 |
| **Jefferson County** | | | | | | | | | |
| West Loco | 21 | 3S | 5W | Magnolia, Featherston Ranch, 1952[1] | IS | Pontotoc | 180 | 20 | 18 |
| West Loco | 21 | 3S | 5W | Mobil, Featherston Ranch, 1953[1] | IS | Pontotoc | 180 | 20 | 18 |
| Seay | 19 | 7S | 5W | Thermal Oil Producers, 1960[1] | IS | Lower Cisco | 850 | 34 | 23-25 |
| **McClain County** | | | | | | | | | |
| East Criner | 21, 28, 29, 33 | 6N | 3W | Sunray-DX, 1965† | MP | 1st & 2nd Bromide | 9600 | | |
| **Murray County** | | | | | | | | | |
| Vines Dome | 34 | 1S | 2 E | Mobil, Vines Dome, 1964† | IS | 2nd Bromide | 1150-1450 | | |
| **Nowata County** | | | | | | | | | |
| Delaware-Childers | 1 | 26N | 16 E | Sinclair, Tanner, 1948[3] | IS | Bartlesville | 600 | 26 | 36 |
| Delaware-Childers | 35 | 27N | 16 E | Sinclair, Tanner-Fee, 1960[5] | IS | Bartlesville | 650 | 30 | 36 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Osage County** | | | | | | | | | |
| Avant | 24<br>19 | 23N<br>23N | 11 E<br>12 E | Sinclair, W. Avant, 1964[5] | IS | Bartlesville | 1600 | 12 | 35 |
| North Burbank | 24 | 27N | 5 E | Phillips, Unit 41, 1965[6] | SD | Burbank | 2950-3000 | 60 | 38 |
| Domes | 2, 3<br>34, 35 | 26N<br>27N | 10 E<br>10 E | Cities Service, Domes, 1961† | MC | Bartlesville | 1800 | 100 | 36 |
| Domes | 15, 16, 21 | 29N | 11 E | ORCO, Hickory Creek 2, 1961† | MC | Wayside | 1080 | | 34 |
| Domes | 25, 35, 36 | 29N | 11 E | ORCO, Hickory Creek 1, 1961† | MC | Wayside | 1080 | | 34 |
| **Seminole County** | | | | | | | | | |
| Seminole City | 16 | 9N | 6 E | Carter, C-2 Block, 1953[3] | MG | Booch | 3500 | 12-32 | 38 |
| **Stephens County** | | | | | | | | | |
| Velma | 9 | 1S | 5W | Harbour & Davis, 1965[1] | SS | Pontotoc | 250-1200 | | 23 |
| Loco | 6 | 3S | 5W | Texas Petr. Engr., 1960† | IS | Pontotoc | 420 | 17 | 22 |
| West Loco | 9 | 3S | 5W | Continental, 1963[1] | IS | | 500-600 | | 21-24 |
| **Tulsa County** | | | | | | | | | |
| Bird Creek | 32 | 21N | 13 E | Texaco, 1962[1] | SS | Tucker | 1300 | | 26 |
| **Washington County** | | | | | | | | | |
| Bartlesville-Dewey | 5 | 27N | 13 E | ORCO, K & S, 1957[7] | MC | Bartlesville | 1250 | 20 | 33 |
| Bartlesville-Dewey | 32 | 28N | 13 E | Forest, 33, 1959[1] | MC | Bartlesville | 1250 | | 33 |

* Thermal methods: HW = hot-water flooding; IS = in-situ combustion; SS = steam stimulation; SD = steam drive. Miscible methods: MC = carbonated water followed by plain water; ME = enriched-gas drive; MG = gas-driven LPG; MP = high-pressure vaporization.

† Active.

[1] Inactive. [2] Inactive 1953. [3] Inactive 1959. [4] Inactive 1964. [5] Inactive 1965. [6] Inactive 1966.

[7] Viscous.

(continued from page 250)
lease. In 1952, Magnolia Petroleum Company developed a small-scale in-situ project in the West Loco area of Jefferson County. These projects and a third one in Missouri have been terminated, but, according to the literature, the expressed purpose of all three was to test methods of igniting the reservoir and collecting performance data.

A total of thirteen in-situ projects have been started in Oklahoma since 1948, five of which are apparently still active. The oldest active project, in the Loco field of Stephens County, dates back to 1960 and has been in operation for six years.

Apparently in-situ combustion has limited possibilities in the Midcontinent area. Widespread development will be curtailed due to limits imposed by present technology, current crude prices, scarcity of suitable reservoirs, and high development and operating costs.

Obviously, a number of inactive projects are still being evaluated. Operators are continuing to gain experience, not only from projects in the Midcontinent area but also from projects in other areas which will enable them to be more selective in screening prospects for development.

*Steam stimulation ("huff and puff").*—Indications are that attempts to stimulate wells by steaming took place prior to the most recent attempts in the years 1964 and 1965. Limited experimental work was attempted in Missouri in 1962, but results were inconclusive.

The accuracy of information pertaining to the steam-stimulation projects is of limited quantity and extremely doubtful quality. Attempts by both large and small operators have not been publicized. Records indicate that approximately thirteen steam-stimulation projects have been inaugurated in the Midcontinent area to date with only four being active at this time; the six known projects in Oklahoma are now inactive. However, it is probable that several additional abortive attempts have been tried but were not publicized. No data are available to substantiate any activity thus far in 1966.

In an attempt to determine the magnitude of steam stimulation in the Midcontinent area, our firm canvassed several service companies and suppliers of steam-stimulation equipment. It became apparent that most of the portable steam generators moved into this area within the last two years are now being moved out of the State into more promising areas.

Most of the reservoirs in Oklahoma fail to satisfy current requirements for successful steam stimulation. Future applications of this method will probably be confined to the removal of contaminants from the sand face in producing wells.

*Steam drive.*—Increased attention has recently been given to the steam-drive method of recovery. The technique is being tested in primary-, secondary-, and tertiary-recovery projects. Two projects have been reported in Oklahoma, one of which is active at this time.

Individual companies are continuing to test the steam-drive method. In May 1966 the Shell Oil Company asked for an allowable increase in its steam-drive project in the Sho-Vel-Tum field in Carter County. This is one of the larger steam-drive thermal-recovery projects in the Midcontinent area, and, according to records of the Corporation

Commission of Oklahoma, comprises 280 acres developed by 40 wells.

Steam drive, as well as hot-water flooding, will be tested extensively during the coming years. If the cost of generating steam can be reduced in conjuction with a price increase for the low-gravity crude oil, development will become much more attractive. Current testing will be instrumental in developing parameters for future development.

*Miscible-phase displacement.*—A limited number of miscible-phase-displacement projects has been developed in Oklahoma since 1953. The earliest reported project was developed in 1953 by The Carter Oil Company (now Humble Oil & Refining Company), in the Seminole City field in Seminole County. The project was terminated in 1959. An LPG slug was injected into the Booch sand, followed by dry-gas injection. An increase in oil production was realized; however, actual results have never been made public. Shell Oil Company conducted two miscible pilot projects in the Elk City field of Beckham County in 1958 and 1959. One of these involved the injection of an LPG slug followed by gas, whereas the other employed enriched-gas injection. Both projects were terminated after a few months of operation. The Continental Oil Company developed a miscible-phase-displacement project in the Short Junction field of Cleveland County; however, no data concerning this project are available.

A high-pressure-vaporization project was commenced in 1965 by Sunray-DX Oil Company in the East Criner field of McClain County. The operator is injecting gas at high pressures into the First Bromide and Second Bromide sands, which are found in this area at a depth of approximately 9,600 feet. This is a comparatively new project.

Only limited application for miscible-phase displacement is foreseen in the immediate future. Limiting factors are the high price of LPG and the low pressures and depleted status of most reservoirs. High-pressure-vaporization projects may be developed in later years as deeper reservoirs are discovered.

Several carbonated-water, or carbon dioxide, floods have been developed in Oklahoma and Kansas. The Oil Recovery Corporation (ORCO) has installed at least three projects in Oklahoma. The Forest Oil Corporation used carbon dioxide on one of its leases in Washington County, and the Cities Service Oil Company has injected carbon dioxide in the Domes field of Osage County.

Available information indicates that no additional carbon dioxide waterfloods have been installed in the Midcontinent area during the past year.

*Chemical additives for waterflooding.*—Although several chemical additives have been tested over the years, only the water-soluble polymers are receiving much attention at this time. Considerable experimental work with polymers is taking place in the Midcontinent area; however, of eight known projects, information is available on only one in Kansas (Keeling, 1966).

## CONCLUSION

Most applications of advanced recovery techniques in Oklahoma have been and are still in the experimental stage of development.

Generally speaking, the oil reservoirs fail to satisfy requirements for commercial application of existing thermal and miscible-phase-displacement techniques. A definite need for new techniques exists, especially in the field of tertiary recovery, which can be applied to oil reservoirs in Oklahoma and similar areas.


**Reference Cited**

**Keeling, L. A.**, 1966, The application of advanced recovery techniques in the Mid-Continent area: Interstate Oil Compact Commission, Committee Bull., vol. 8, no. 1, p. 11-19.


# UPPER SILURIAN OR LOWER DEVONIAN CONODONTS OF MIDDLE ASIA AND PAKISTAN


CARL C. BRANSON


By a remarkable coincidence, conodont faunules of like age have been simultaneously described from West Pakistan (Barnett and others, 1966) and from middle Asiatic Russia (Moskalenko, 1966). Conodonts of this age have not been described earlier. Barnett and others described and illustrated 18 conodont species from limestone reef rock east of Peshawar in the northern part of West Pakistan. Macrofossils indicate a Silurian or Devonian age. The Russian faunule of 10 species is from beds bearing the tentaculite *Novakia* and the graptolite *Monograptus hercynicus* in the Kshtut River valley of middle Asian Russia near Zeravshan.

The two faunules are remarkably similar. Names are tabulated here with those of like or related forms opposite each other in parallel columns.

| WEST PAKISTAN | MIDDLE ASIA |
|---|---|
| *Belodella devonica* (Stauffer) | *Belodus asiaticus* Moskalenko |
| *Spathognathodus remscheidensis* Ziegler | *Spathognathodus optimus* Moskalenko |
| *Hindeodella* sp. | *Hindeodella kshtutensis* Moskalenko |
| *Ozarkodina denckmanni* Ziegler | *Ozarkodina denckmanni* Ziegler |
| *Trichonodella inconstans* Walliser | *Trichonodella zeravshanica* Moskalenko |
| *Panderodus* sp. | *Paltodus unicostatus* Branson and Mehl |

A platform-type conodont assigned to *Polygnathus* and a species of *Synprioniodina* also occur in the Russian faunule and *Lonchodina, Neoprioniodus,* and *Plectospathodus* in the West Pakistan faunule. The assignment of a species to *Polygnathus* seems inexact and the identification of *Paltodus unicostatus* cannot be validated by the specimens figured.

The two faunules appear to be earliest Devonian in age.

**References Cited**

**Barnett, S. G., Kohut, J. J., Rust, C. C., and Sweet, W. C.,** 1966, Conodonts from Nowshera reef limestones (uppermost Silurian or lowermost Devonian), West Pakistan: Jour. Geology, vol. 40, p. 435-438, pl. 58.

**Moskalenko, T. A.,** 1966, Pervaya nakhodka pozdnesiluriiskikh konodontov v zeravshanskom .khrebte: Akad. Nauk SSSR, Paleontologicheskii Zhurnal, no. 2 (1966), p. 81-92, pl. 11.

## Technique for Mounting Saccate Pollen Grains

Robert B. Sanders

During a study of the morphology of Recent pine pollen, it was necessary to find a mountant or mounting technique which does not cause distortion of the grains. Acetolyzed pollen preserved in methanol, ethanol, glycerine, xylene, or water were mounted on microscope slides in diaphane, glycerine jelly, Polyvinol, Clearcol, Harleco synthetic resin, Canada balsam, and Hoyer's solution. Of these, only Hoyer's solution proved satisfactory in eliminating the distortion of grains; the solution was found to cause only occasional collapse of the sacci, but the collapsed sacci reexpanded within hours.

Hoyer's solution has an index of refraction close to that of unstained pine pollen, a condition which causes the pollen to become almost invisible in transmitted light. Attempts were made to stain the pollen grains with malachite green, Bismarck brown Y, methyl blue, safranin O, and gentian violet, but the dyes were not retained by the grains and bled into the surrounding medium. Staining of the Hoyer's solution with these dyes proved of little value in making the grain visible, except in the cases of safranin O and Bismarck brown Y. Hoyer's solution, stained dark red with Bismarck brown Y, proved to be the most satisfactory, the pollen grains absorbing enough stain to make them stand out distinctly. The presence of alcohol as a pollen preservative-carrier causes the stain to separate, resulting in a mottled mountant. Therefore, alcohol must be removed by centrifugation with water before proceeding with the mounting process.

The most successful mounting procedure is to place a drop of the pre-stained Hoyer's solution on a microscope slide and add to it one drop or less of the pollen in an aqueous carrier. The pollen and Hoyer's solution are mixed thoroughly over the entire area to be covered by the glass cover slip. Elimination of bubbles is best accomplished by setting one edge of the cover slip near the edge of the prepared area and slowly lowering the cover slip into position. The slide should be heated on a warming table at about 37° C for 1 to 3 days. The excess mountant is easily scraped from around the cover slip with a razor blade after the slide has dried.

As this mountant does not dry completely, the grains have a slight tendency to move under pressure. If the mountant is composed of approximately equal parts of aqueous carrier and Hoyer's solution, this mobility is insufficient to cause problems in normal procedures. Excess water, however, will cause the mountant to remain too fluid for normal handling for several weeks.

The method described by Wilson (1962), in which the Hoyer's solution and pollen are dried upon a glass cover slip before mounting, was found undesirable for pine pollen, as the collapse of the sacci is not prevented.

Hoyer's solution may be obtained either commercially or prepared in the laboratory (Wilson, 1962). Enough Bismarck brown Y powder should be added to the Hoyer's solution to color the mountant dark red, or claret. Approximately 0.05 gm of Bismarck brown Y powder per 10 gm of Hoyer's solution is suggested. The pre-stained Hoyer's solution may be stored indefinitely.

**Reference Cited**

**Wilson, L. R.**, 1962, Use of Hoyer's solution as a palynological mounting medium: Okla. Geol. Survey, Okla. Geology Notes, vol. 22, p. 26-27.

## *Lingula* in the Wellington Formation (Permian) of Oklahoma

Stephen A. Hall

Numerous specimens of *Lingula* occur in a roadside cut on the west side of a curve in the section-line road 0.5 mile east and 4.6 miles north of the junction of U. S. Highway 64 and Interstate 35, near insect locality 16 of Carpenter (1947), SE¼ NE¼ sec. 32, T. 22 N., R. 1 W., Noble County, Oklahoma. The brachiopods are in a 6-inch red shale 8 feet below the base of the Billings Pool Sandstone of Raasch (1946) in the Midco Member of the Wellington Formation.

The *Lingula* valves are concentrated in a 2-inch zone 3 inches above the base of the red shale. The valves are oriented in no particular manner, and only a few specimens of conjoined valves are preserved.

The gray to dark-green, fissile shale below the *Lingula*-bearing shale contains many conchostracans and a few plates or scales. A few conchostracans occur in the red shale in association with *Lingula*. No fossils were found in the gray-green, lumpy shale overlying the *Lingula* bed.

Fifteen complete valves were collected and measured. The valves range from 3.0 to 7.0 mm in width and from 5.5 to 13.0 mm in length.

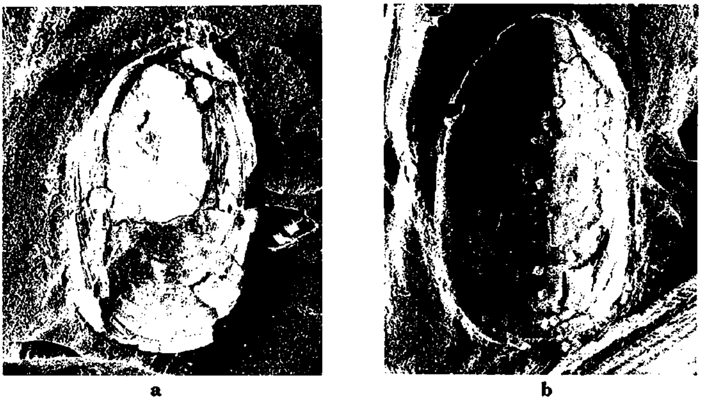

**Figure 1. Lingula sp., x4, from the Wellington Formation, Noble County, Oklahoma.**
**a. Exterior of valve, OU 5570.**
**b. Interior of valve, OU 5569.**
(Photographs by William P. Vick)

The average dimensions of the fifteen valves are 6.4 mm in width and 10.6 mm in length.

*Lingula* is the first marine fossil found to occur in the upper part of the Wellington Formation. Tasch (1964) reported *Lingula* in a 1-foot bed 6 feet above the base of the Wellington Formation in Kansas. Tasch interprets the lithologic-paleontologic sequence as that of a regressing epeiric sea, the *Lingula* bed representing a nearshore deposit. The sequence observed in the upper part of the Wellington appears to be a reversal of the transition from marine to continental environment reported at the base of the Wellington. However, the absence of fossils above the *Lingula* bed at the exposure and the occurrence of mud cracks in the upper 1 inch of the *Lingula* bed argue against such a possibility.

Whether the delicate brachiopod valves were transported into the area or *Lingula* lived at the locality for a short time, the presence of these valves indicates a definite connection with a marine environment at least once during Wellington time subsequent to the regression of the Early Permian sea.

#### References Cited

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**Raasch, G. O.,** 1946, The Wellington formation in Oklahoma: Wis., Univ., unpublished doctoral dissertation.

**Tasch, Paul,** 1964 [1966], Periodicity in the Wellington Formation of Kansas and Oklahoma, in Merriam, D. F., ed., Symposium on cyclic sedimentation: Kans., State Geol. Survey, Bull. 169, p. 481-496.

## Kansas Geological Society Field Conference

The Kansas Geological Society has announced preliminary plans for its Twenty-ninth Annual Field Conference. The conference will take place November 3-5, 1966, in cooperation with the Arkansas Geological Survey. Field-trip leaders will be L. M. Cline, University of Wisconsin; Boyd Haley, U. S. Geological Survey; Charles Stone, Arkansas Geological Survey; George Viele, University of Missouri; and Phillip Stark, Mobil Oil Company.

The purpose of the conference will be to study the depositional environment and tectonic history of flysch sediments in the Ouachita Mountains of Oklahoma and Arkansas. Marginal-marine (showing upright tree molds in the Arkoma basin), shelf, and upper-slope strata will be traversed to provide a comparative model for interpertation of flysch facies. Varieties of flysch will be examined to explain source, direction and mode of transportation, and lithic characteristics related to depositional environment. Evidence for nappe structures in the Arkansas Ouachitas will be presented.

Registration will be on Wednesday, November 2, 1966, at Fort Smith, Arkansas. The registration fee of approximately $30.00 will include bus transportation, three breakfasts, three lunches, banquet, and guidebook. Overnight stops are planned for Hot Springs and Little Rock, Arkansas. Complete information may be obtained by communicating with Virgil M. Tucker, Champlin Petroleum Company, 1632 Wichita Plaza, Wichita, Kansas 67202.

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