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STRIP MINE IN EASTERN OKLAHOMA

The picture is an airplane vertical photograph taken in 1952. The four-section area is sections 20, 21, 27, and 28, T. 19 N., R. 15 E., in Wagoner County.

The principal feature to be seen is the belt of parallel ridges which are the linear waste heaps from coal stripping. The steep wall on the west edge of the stripped area is the "high wall," which was the last working face, and at its foot is the last coal floor to be worked. The depression is not filled in on this last row and it now contains a lake with water level at the water table. The rim of the west wall is the Verdigris Limestone. The coal bed which was mined here is the Croweburg coal, called the Broken Arrow coal in the Tulsa-Claremore region and called Henryetta coal near Okmulgee and Henryetta. The coal is 19 to 22 inches thick and is high-volatile bituminous. It is no longer mined in this area because the overburden is 30 feet and includes the Verdigris Limestone. It is being mined now in Rogers County west of Catoosa and west of Sequoyah.

Doerr (1961, fig. 13) illustrated the adjacent pit to the north. The belt of stripping in the Croweburg coal extends almost continuously from west of Oneta to the north line of Wagoner County and at places is more than half a mile wide.

Govett has mapped the county and he showed the entire area as underlain by the Senora Formation (1959, pl. I). The Verdigris Limestone is the sole resistant member in the area of the photograph, an area otherwise underlain by shales. The southeastward-flowing stream is a branch of Adams Creek.

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Geophysical Detection of Faulting, South Sparks Area, Lincoln County, Oklahoma

J. A. E. Norden and J. E. King

INTRODUCTION

Geological investigations (Cole, 1955; Masters, 1955; Morgan, 1958) in Lincoln County, Oklahoma, have revealed challenging problems in the accurate delineation of faulting which controls the structural position of petroleum reservoirs. The mapping of the fault zones depends, however, on the density of the well control. In some areas which have insufficient subsurface data for the correlation the mapping of the fault zones remains in the realm of inference based on assumptions and probability of subsurface ties.

This problem stimulated a decision to run a test survey along a profile selected for this comparative study in order to investigate the resolving power of different geophysical methods for detection of fault zones in such areas. The South Sparks area in Lincoln County was chosen for the investigation. The area is about 1.5 miles southeast of Sparks in the vicinity of the South Sparks pool (secs. 19 and 30, T. 13 N., R. 4 E.) and is here called the South Sparks area.

The length of the test profile was 600 feet in a north-south direction along the road between secs. 19 and 20 of T. 13 N., R. 5 E.

Subsurface geological conditions in this particular location pointed to the possibility of faulting (King, 1962). The geophysical test was performed to verify the existence of this suspected fault zone.

VERTICAL MAGNETIC INTENSITY PROFILE

A vertical magnetic intensity survey was run for reconnaissance purposes. Measurements were made by a Ruska Type V-3, Vertical Magnetometer, no. 5708. The instrument was set to a sensitivity of 10.01 gammas per scale division and the temperature correction factor was +0.1 gamma per 1 °C. Field data were corrected for temperature, diurnal, and geomagnetic latitude variation and are plotted in figure 1.

The magnetic vertical intensity profile revealed two zones along the line where steplike breaks were shown as local anomalies. These sudden variations in the magnetic vertical intensity appeared to develop between stations 2 and 3 in the north half of the profile and at stations 8 and 11 on the south end of the line. These changes in magnetic vertical intensity (ΔV), however, were small, in the range of 8 gammas. This magnetic relief may relate to a small polarization contrast equal to 0.000012, in which case the corresponding susceptibility contrast (for $H=0.558$) would be about 21.6×10^{-6}. Susceptibility of the outcropping Lower Permian sediments of Konawa age (Cole, 1955) along the profile was tested with a Magnetic Susceptibility Bridge, Model MS-3, made by the Geophysical Specialties Company, Hopkins, Minnesota. Magnetic susceptibility measurements by the MS-3 are made in a magnetic field of the same order of magnitude as that of the earth's field.

The field used in the MS-3 is produced by alternating current and the instrument neither measures nor is affected by remanent magnetization (Geophysical Specilties Company Manual, 1962). Susceptibility tested on Permian sediments in the South Sparks area was found to be in the range of 10×10^{-6}, which is much lower than the value of susceptibility contrast computed above for an 8-gamma relief. One may assume that the 8-gamma magnetic relief was caused by the difference in polarization in the near surface sediments. If the sediments beneath the surface were faulted and their displacement was large enough relative to the depth of faulting, this geological condition may hold as an explanation of the small magnetic relief still detectable under a low polarization contrast (Nettleton, 1940). The small magnetic variations under the possible conditions referred to above invited further investigation of this problem by a seismic refraction survey along the magnetic profile.

SEISMIC-REFRACTION PROFILE

Six seismic-refraction lines, each 100 feet long, were laid out in a continuous tie. Seismic-refraction measurements were made by an Engineering Seismograph, Model MD-1, made by the Geophysical Specialties Company, Minneapolis, Minnesota. With a sledge hammer used for the source of energy, the maximum depth of penetration along a 100-foot line was computed to be 34 feet. The computed and correlated seismic-refraction horizons are plotted in figure 1.

Three seismic media were recognized:

V_1 medium, average velocity 1243 ft/sec

V_2 medium, average velocity 1917 ft/sec

V_3 medium, average velocity 3470 ft/sec

Four tectonic displacements were recorded on the V_3 medium. These displacements, which ranged from 3 to 10 feet in magnitude, were in the zones where sudden magnetic variations were recorded.

Considering the fact that these displacements of the near-surface Permian beds represent a quantitative control of the geology by the refraction seismograph, one may interpret as the cause of these shallow faults a readjustment movement, both in the Permian and in the Pennsylvanian rocks above a pre-Pennsylvanian fault zone. These readjustment movements affected the younger sediments as a "rejuvenation" of fault zones across the unconformities. This would have a bearing on the photogeological linear trends observable in Lincoln County at places where such younger readjustment lines intersect the surface formations. We have geophysically tested similar conditions in the South Norman area, Cleveland County, Oklahoma.

EARTH-CURRENT POTENTIAL PROFILE

In order to obtain additional information on the possible application of the electrical self-potential method in the reconnaissance delineation of fault zones, a self-potential survey was made parallel with the

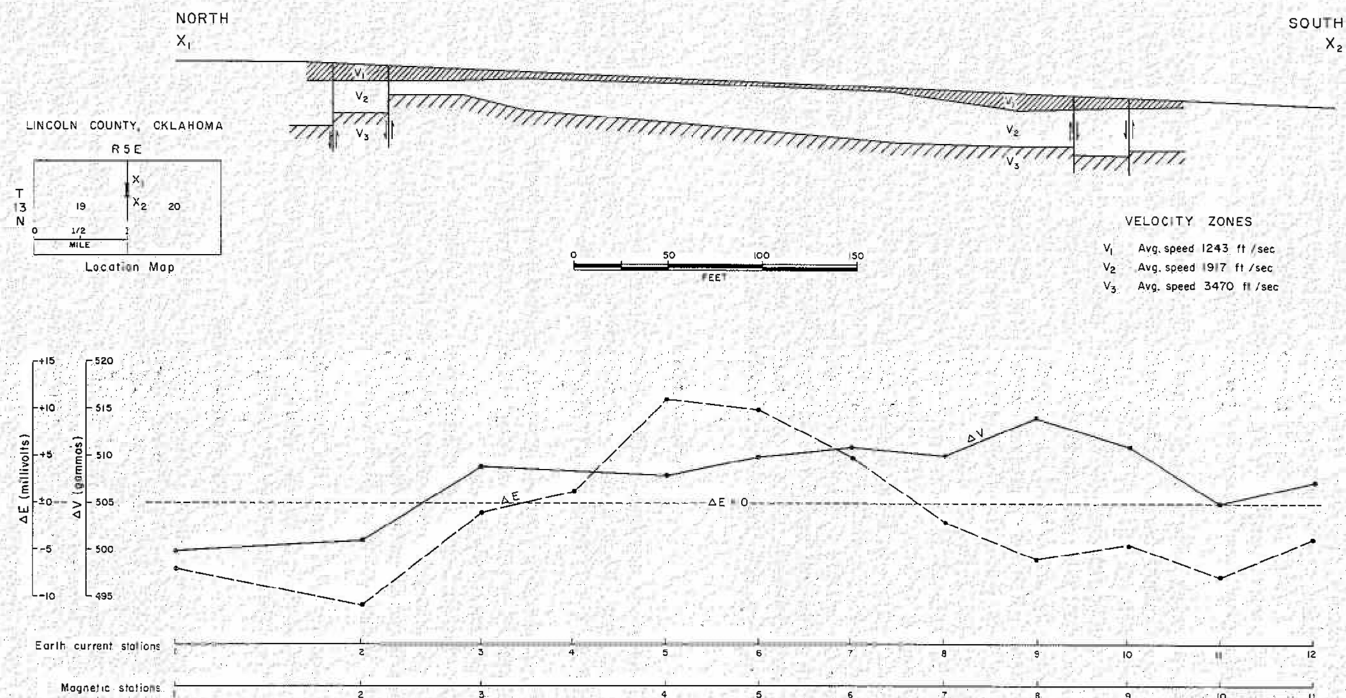

Figure 1. Geophysical cross sections of a line in the South Sparks area, Lincoln County, Oklahoma. All sections, seismic (upper part of diagram), variation of vertical magnetic intensity (ΔV), and variation of earth-current potential (ΔE), are drawn to the same horizontal scale. The ratio of the vertical to horizontal scales of the seismic section is 1:1.

magnetic and seismic profiles. The instrument used in this survey was a Geovolt apparatus manufactured by the Georator Corporation, Manassas, Virginia. Potential differences were tested at various intervals with porous pot electrodes. With polarization differences noted, the potential differences are shown as progressive addition along the test profile (fig. 1).

A potential high with a total relief of 22 millivolts is indicated between the two faulted zones. The fault zones are shown by trough-shaped depressions of the potential graph (ΔE). At the north and south ends of the potential profile a slight similarity can be noticed between the electrical potential and the vertical magnetic intensity variation. This may be explained, perhaps, by the effect of natural earth currents. These currents of global extent flow through the earth's crust and may result in potential differences (Dobrin, 1960). It is difficult to separate these telluric currents from electrochemical potentials which could be caused, for instance, by chemical differences of the materials' coming in contact with solutions (Heiland, 1946). Earth currents flow everywhere in large sheets along the surface of the earth and, depending upon the resistivity of the formations carrying the currents, they by-pass the media of higher resistivity and thereby produce a distortion of the potential gradients at the surface (Dobrin, 1960). These distortions may develop along fault lines if the upthrown medium produces a strong enough resistivity contrast to deflect the telluric currents.

CONCLUSION

Geophysical test surveys in the South Sparks area, Lincoln County, Oklahoma, confirm the usefulness of magnetic and electrical self-potential methods as a reconnaissance approach in the delineation of fault zones.

A shallow refraction seismic survey across these fault zones proved to be a quantitative control on the faulting indicated by magnetic and electric self-potential methods.

Shallow faults may be interpreted as a result of readjustment movements of younger sediments above an older faulted zone.

Photogeologic linear trends of the tectonic microstain may be correlated with these shallow fault zones recorded by the refraction seismograph.

The economy and speed in these geophysical surveys, with the information obtained by them, justify the advantageous use of these methods in co-ordination with geological investigations.

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A New Slide-Marking Ink

DONALD O. NELSON

A common practice in palynological work is to mark specimen locations in slides with glass-marking ink for future reference. Most commercially available inks either are opaque or are not permanent. Also, because of opacity, considerable areas of the slide are obscured when specimens have been ringed. This condition is a handicap to statistical studies if the same slides must be used for frequency counts.

A recently developed permanent transparent ink can easily be made from a mixture of Lakeside 70 mounting medium, isopropyl alcohol (91%), and safranin O stain. Any other alcohol-soluble stain can be used, depending upon the worker's preference as to color. This ink dries quickly, is moisture and heat resistant, durable, and transparent. Specimens under the ink can be readily identified, and the worker can easily continue his counting through the rings and numbers.

The materials used are readily obtainable, and the preparation is simple. The proportions given below will yield approximately one-third ounce of slide-marking ink.

Lakeside 70	5 g or 2.5 cm of stick
isopropyl alcohol (91%)	10 cc
safranin 0 stain	20 mg

The Lakeside 70 is dissolved in the alcohol in a one-ounce, wide-mouth, screw-cap specimen bottle, and then the stain is added.

Repeated opening of the bottle will cause an increase in viscosity due to the evaporation of the alcohol. Additional alcohol should be added from time to time to maintain a good working viscosity. Lakeside 70 is slightly soluble in xylene; therefore caution is necessary when cleaning slides after the use of an oil-immersion objective. A weak detergent solution should be used if additional cleaning is necessary after removal of the oil with lens paper.

A Middle Pleistocene Stream Channel

Arthur J. Myers

The area of this study is covered by the Woodward topographic sheet (scale 1:250,000) in northwestern Oklahoma and includes the area from 36 to 37 degrees north latitude and from 98 to 100 degrees west longitude (fig. 1). Across this area the Cimarron River and North Canadian River parallel each other, flowing in a southeasterly direction approximately 20 miles apart. The gradients of the rivers are nearly the same, but the Cimarron is approximately 400 feet lower in elevation. The Cimarron River enters the area in the northwest at an elevation between 1,600 and 1,700 feet and leaves the area in the southeast at an elevation of approximately 1,000 and 1,100 feet. The North Canadian River in the northwest is at an elevation of approximately 2,150 feet and in the southeast at approximately 1,550 feet. The writer believes that the positions of the present courses of the two streams were determined primarily by the existence of an Early Pleistocene stream channel, the deposits of which now occupy the area between the streams.

The rock units of the area include (ascending): the Permian Flowerpot Shale, Blaine Formation, Dog Creek Shale, Marlow Formation, Rush Springs Sandstone, and Cloud Chief Formation; the Pliocene Laverne Formation and Ogallala Formation; and the Pleistocene Crooked Creek Formation. The topography in the general area of the two rivers comprises a gently rolling higher plain in the southwestern half and a highly dissected lower plain in the northeastern half, with the divide between the rivers being the dividing line.

The Cimarron River is a large braided stream, has a broad flood plain, and has eroded its channel into the Flowerpot Shale, which in many places forms steep escarpments along the river. Numerous northeastward-flowing tributaries have cut canyons 25 to 70 feet deep into the Flowerpot and Blaine of the lower plain and have eroded headward to the scarp of the higher plain, some having cut back to less than five miles from the North Canadian River. The large number of tributaries is a result of the impermeability of the shales of the Flowerpot and Blaine Formations.

The North Canadian River is a smaller stream on the higher plain. It has eroded its channel through the Laverne and Ogallala into the Rush Springs. North of the North Canadian River is a belt of dune sand, which ranges in width from 6 to 11 miles, and, because of the high permeability of the dune sand, the river has few southward-flowing tributaries. South of the North Canadian River the Permian Rush Springs Formation, being less permeable than the dune sand, has more runoff and, as a result, there are a few northeastward-flowing tributaries in broad valleys with gentle slopes.

Between the two rivers is a divide composed of alluvium covered with sand dunes. The divide is 150 feet higher than the North Canadian and 5 to 8 miles distant from it, and is 550 feet higher than the Cimarron and 15 to 20 miles from it. The divide is composed of stream-

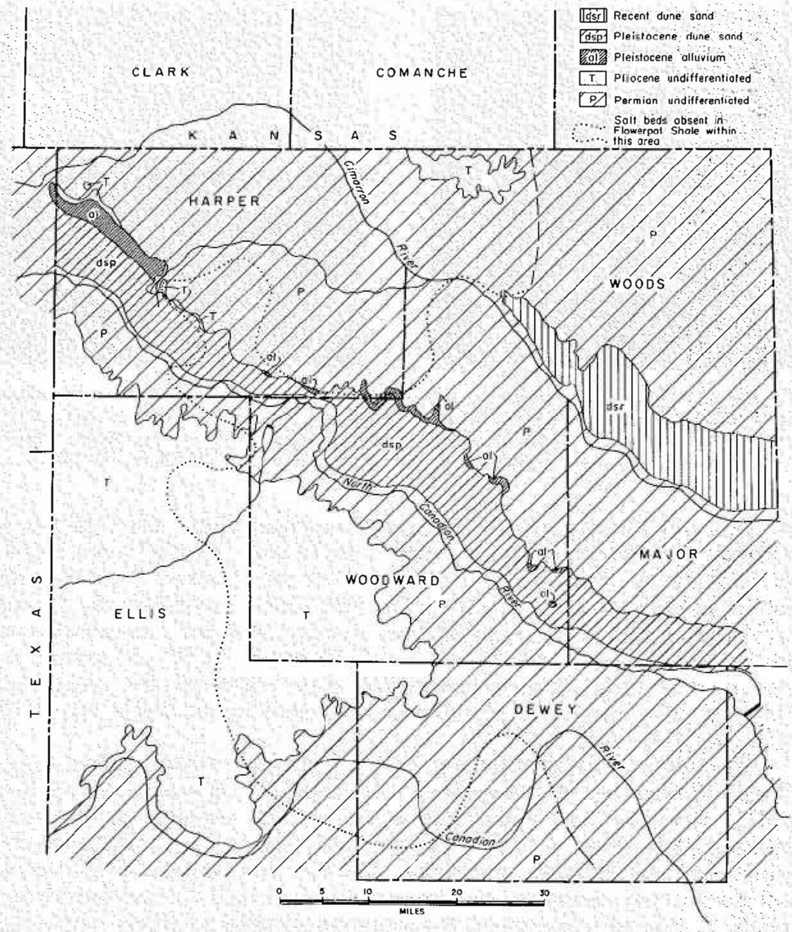

Figure 1. Generalized geologic map of northwestern Oklahoma showing known outcrops of Crooked Creek Formation and area in which salt is absent in the underlying Flowerpot Formation. Pleistocene dune sand (dsp) is derived from sediments of the Crooked Creek Formation; Recent dune sand (dsr) is derived from the alluvium of the present-day Cimarron River.

channel deposits laid down during Pleistocene time by a southeastward-flowing meltwater stream from the Rocky Mountains, which subsequently filled the channel with alluvium. The channel, as mapped by the writer, extends diagonally southeastward from the northwest corner of Harper County to the southeast corner of Woodward County. The alluvial deposits are discontinuous, having been removed at places by Late Peistocene to Recent erosion. The alluvial beds have been assigned to the Crooked Creek Formation (Kansan-Yarmouth) of the Meade Group of the Pleistocene and include the fluvial gravels, sands, silts, and volcanic ash that rest upon the Pliocene Ogallala Formation

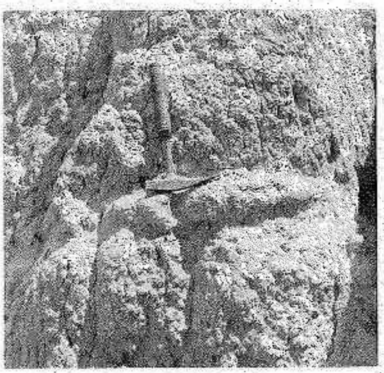

Figure 2. Elephant tusk in silt beds of the Crooked Creek Formation. Tusk is in horizontal position immediately below pick.

Figure 3. Silt beds of the Crooked Creek Formation. These are probably flood plain deposits, NE¼ SW¼ sec. 1, T. 24 N., R. 20 W.

or upon the Permian Rush Springs Sandstone where the Ogallala is missing. The thickness ranges from 0 to 70 feet. In NE¼ sec. 10, T. 28 N., R. 26 W., the Pearlette Ash Lentil of the Crooked Creek Formation is present. Stephens (1960, p. 1680-1684) identified the Stump Arroyo Member (Kansan) and the Atwater Member (Yarmouth) of the Crooked Creek in SW¼ sec. 20, T. 27 N., R. 24 W. At several localities thin beds of montmorillonite may represent the weathered Pearlette Ash, and an elephant tusk is present in the SW¼ sec. 1, T. 24 N., R. 20 W. (fig. 2).

The wide range in lithology reflects various environments of deposition. Within the old channel are boulders of red sandstone up to a foot in diameter. At many places are gravels ranging in size from granules to boulders 4 to 6 inches in diameter, the boulders commonly being quartzite or black sandstone. Pebbles and cobbles of orthoclase and quartz are abundant locally, as are reworked Cretaceous oyster shells. A typical exposure of the alluvium consists of sands with gravels of various sizes and compositions (fig. 4). The bank of the stream

Figure 4. Typical surface exposure of unconsolidated Crooked Creek Formation, SE¼ SE¼ sec. 6, T. 21 N., R. 16 W. Pebbles are commonly quartzite, quartz, and orthoclase.

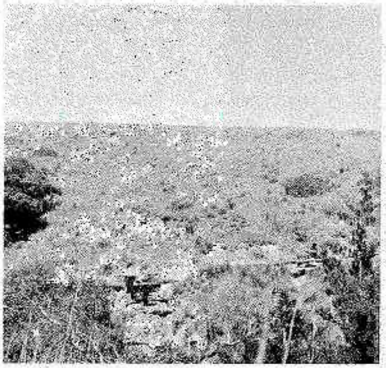

Figure 5. Crooked Creek sands and gravels with lithified basal part unconformably overlying Permian Rush Springs Formation, NE¼ sec. 7, T. 24 N., R. 19 W.

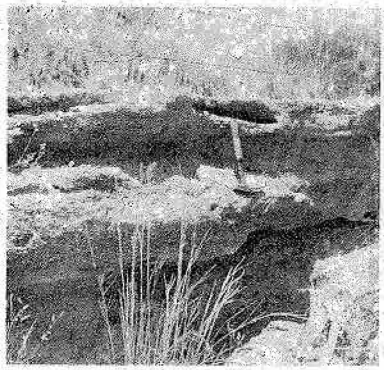

Figure 6. Basal conglomerate of the Pleistocene Crooked Creek Formation, near outcrop shown in figure 5.

channel, eroded into the Permian Rush Springs Sandstone and subsequently buried, is exposed in the NE¼ sec. 33, T. 25 N., R. 20 W. The basal portion is in most places coarse grained and well cemented (figs. 5, 6).

The sands are generally tan and cross-bedded, and headward erosion of a stream has exposed a good section in secs. 4 and 5, T. 21 N., R. 17 W. In sec. 35, T. 21 N., R. 17 W., the sand contains nodules of red mudstone up to eight inches in diameter (fig. 8). The stratified silt beds, ranging in color from buff to tan and from gray to black, are probably flood-plain deposits, and their position north of the coarser clastics indicates that the central part of the channel was closer to the North Canadian than to the Cimarron (fig. 3). It was in these silt

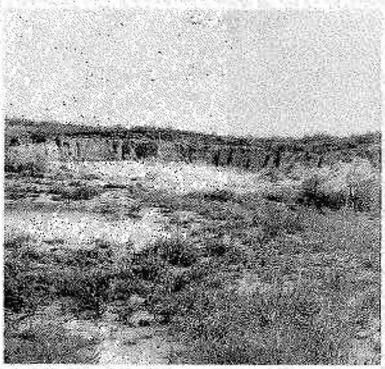

Figure 7. Crooked Creek sand with overlying sand dunes, SW¼ SW¼ sec. 35, T. 21 N., R. 17 W.

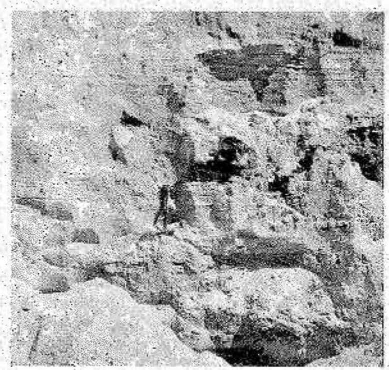

Figure 8. Close-up view of outcrop shown in figure 7 showing cross-bedded Crooked Creek sand with red mud balls.

beds that the elephant tusk (fig. 2) was found. In most places the wind has reworked the surface material, forming dunes which are now stabilized by vegetation (fig. 7). Because of erosion and the dune cover, the original width of the channel is unknown but outcrops are as much as four miles apart (fig. 1).

The Pliocene Ogallala Formation has a maximum thickness of 35 feet in Harper County and 195 feet in Woodward County. How far east the cover extended at the end of Pliocene time is questionable, but it probably was present over all of Harper and Woodward Counties; therefore at the beginning of the Pleistocene the surface of the area was at the High Plains level. It is not known whether Nebraskan streams crossed the area nor how much erosion had taken place during that time.

In northwestern Oklahoma and southwestern Kansas the Flowerpot Shale contains between 200 and 300 feet of salt within 600 feet of the surface; however, salt is absent in most of the area underlying the stream channel (fig. 1). By the beginning of Kansan time removal of salt from the Flowerpot, and consequent collapse, could have formed a topographic low which would have channeled the meltwater from the Rockies. The meltwater eroded a channel into the Ogallala and Rush Springs and subsequently filled it during the latter part of Kansan time and during Aftonian time. By Illinoisan time the channel was abandoned and the highly permeable alluvium of the stream channel allowed infiltration of runoff. Continued removal of salt formed shallow sinkhole basins and some of these formed fresh-water lakes, which were subsequently filled with material washed into them from the surrounding area. One lake basin formed in the old stream channel, but others formed in the Permian rocks, showing that the Ogallala had been removed by this time. With the removal of the Ogallala the more impermeable Permian rocks had more runoff and stream channels formed on either side of the Pleistocene stream. In Beaver County the Cimarron River is an east-southeastward-flowing stream, but in northwestern Harper County it swings abruptly northward, flowing into Clark County, Kansas, and thence swings back to the southeast. In Clark County it flows through three large compound sink basins which must have influenced its course, and in northwestern Oklahoma it flows parallel to the strike of the beds and is a subsequent stream. The courses of the present-day Cimarron and North Canadian Rivers have been influenced by the middle Pleistocene stream, the development of sinks, and the strike of the Permian rocks.

The high permeability of the dune sand and of the alluvium of the stream channel has permitted rapid infiltration of rainfall south of the divide so that the northern tributaries of the North Canadian River are short and poorly developed and carry little runoff. Conversely, the drainage area of the Cimarron and its tributaries is underlain by the more impermeable Permian rocks, and a greater proportion of the rainfall has gone into runoff. Consequently, the Cimarron tributaries are well developed, and denudation has proceeded at a more rapid rate in the Cimarron drainage than in the North Canadian drainage, resulting in a difference in elevation of 400 feet between the two systems.

The writer has not examined in detail the deposits in Major County, but he has seen sands and gravels which are similar to those in Harper and Woodward Counties and which he believes represent a continuation of the stream channel. Fay (1959, p. 11) stated that the high-level gravels that are scattered over the countryside in Blaine County probably are of Kansan age and that all major streams in Oklahoma must have existed during Nebraskan time. The writer agrees as to the age of the gravels because they are probably a continuation of the old stream channel. The alluvial deposits in Harper, Woodward, and Major Counties are not associated with either the Cimarron River or North Canadian River and therefore must be older. In T. 6 N., R. 28 ECM, in Beaver County the Cimarron cuts across the channel deposits, which probably continue into Meade County, Kansas.

Kitts (1959, p. 15) stated that the high terraces along the Canadian River in Dewey County contain deposits of Pearlette Ash and therefore are Kansan in age. In northwestern Oklahoma there is no evidence of streams of Nebraskan age; the Canadian River was formed at the latest by Kansan time, and the North Canadian and Cimarron are no earlier than Illinoisan and possibly only Wisconsinan.

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New Survey Publications

Circular 59, *Permian vertebrates from Oklahoma and Texas,* by Everett C. Olson and Herbert Barghusen, was issued August 13, 1962 (title page is erroneously dated July 1962). The book consists of two parts. Part I, by Olson and Barghusen, comprises descriptions of an amphibian and three reptiles from the Flowerpot Formation. The amphibian is of a new genus and two of the reptiles are of new species. Part II, by Olson, is a discussion of the osteology of *Captorhinikos chozaensis,* a species common to the Choza Formation of Texas and the Hennessey Formation of Oklahoma. The book has 68 pages, 15 figures, and 3 plates. Price: $1.50 paper bound, $2.50 cloth bound.

Circular 60, *Crinoids from the Oologah Formation (Pennsylvanian), Tulsa County, Oklahoma,* by Harrell L. Strimple, was issued July 26, 1962. The book is a description of a large fauna comprising 45 species which represent 33 genera and 16 families. Sixteen species are new. The book consists of 75 pages and 9 plates. Price: $1.50 paper bound.

Thenardite Efflorescence in Permian Gypsum, Western Oklahoma

Charles J. Mankin

Thenardite (Na_2SO_4) is a soluble salt that commonly occurs as an efflorescence in association with chemical rocks, particularly evaporites. In the Permian evaporite deposits of western Oklahoma, thenardite is present as a white, powdery encrustation on surfaces and as filling in fractures and small cavities in the outcropping gypsum beds. Figure 1 shows a typical occurrence of thenardite filling bedding-planelike cavities in a sample of Nescatunga Gypsum. Figure 2, a magnification of a portion of figure 1, shows the discontinuous nature of the fillings.

The salt was identified as thenardite by X-ray diffraction and confirmed by differential thermal analysis. The X-ray diffraction data were obtained with a Siemens Crystalloflex IV X-ray generator and recorder using copper radiation. The samples used in the analyses were hand-picked from the cavity fillings in order to avoid contamination with gypsum. But the X-ray diffractogram shown in figure 3 contains diffraction maxima for both thenardite and gypsum, showing that the cavities were filled by co-precipitation of the two minerals. Based upon a first-order approximation of the relative diffraction intensities of the *020* plane in gypsum and the *111* plane in thenardite, it can be

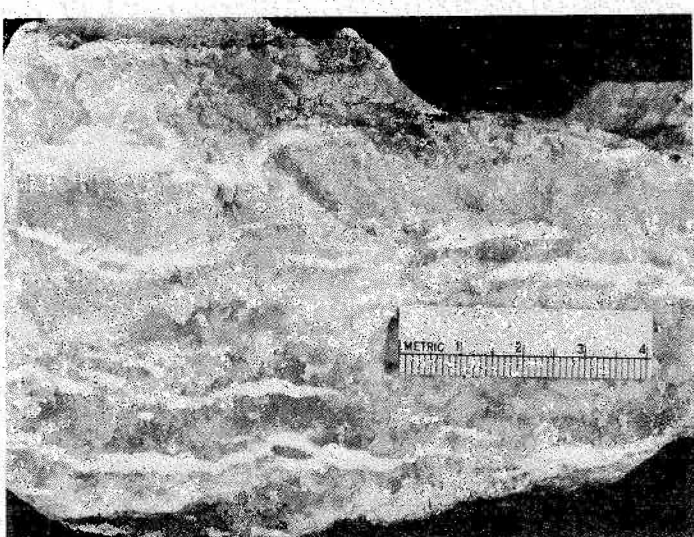

Figure 1. Sample of gypsum showing filling of bedding-planelike cavities by thenardite from Nescatunga Gypsum at U. S. Gypsum Company quarries, Southard, Oklahoma. Sample supplied by D. F. Underwood.

estimated that the ratio of thenardite to gypsum in the cavity fillings is 10:1.

The differential thermal analyses were made with a Stone dynamic gas model 13-M DTA unit. The inert atmosphere was provided by using nitrogen gas as the purging medium. The differential thermogram in figure 4 shows a large endothermal peak at 155°C and a small exothermal peak at 360°C, which essentially correspond to the thermal reactions for gypsum. A standard sample of pure gypsum will give a double endotherm with the second endothermal peak at about 165°C. The second endotherm has a slightly smaller magnitude than the first. According to West and Sutton (1954), the first endotherm corresponds to the loss of 1½ molecules of water forming the hemihydrate. The second endotherm results from the loss of the remaining ½ molecule, forming soluble anhydrite. The exotherm at 360°C results from the change of soluble anhydrite (gamma $CaSO_4$) to anhydrite (beta $CaSO_4$). West and Sutton recorded temperatures of 180°C and 215°C for the two endothermal peaks of gypsum. These temperatures are 25°C and 40°C higher than those recorded in this laboratory. This temperature difference is largely a result of (1) the difference in heating rate of 15°C per minute for the work described by West and Sutton and of 10°C per minute used in this laboratory, and (2) a probable difference in the flow rate of the purging gas.

The absence of the pronounced double endotherm for gypsum in the thermogram (fig. 4) results from the probable interaction of the gypsum dehydration with the thenardite.

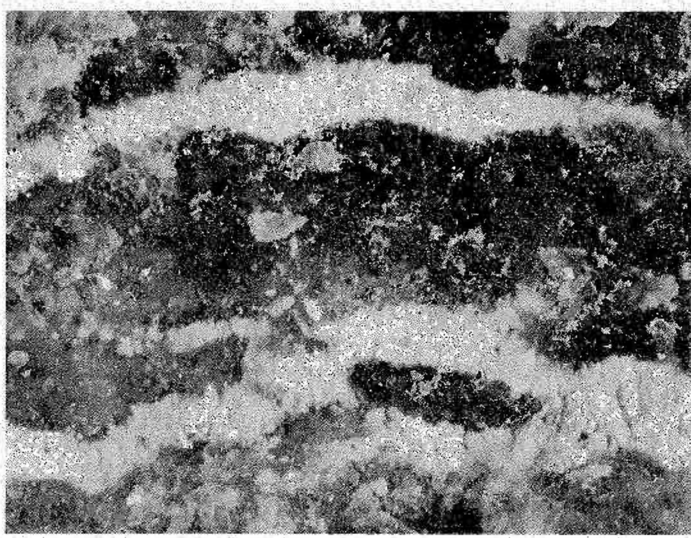

Figure 2. Enlargement (x4) of portion of figure 1 showing nature of cavity filling.

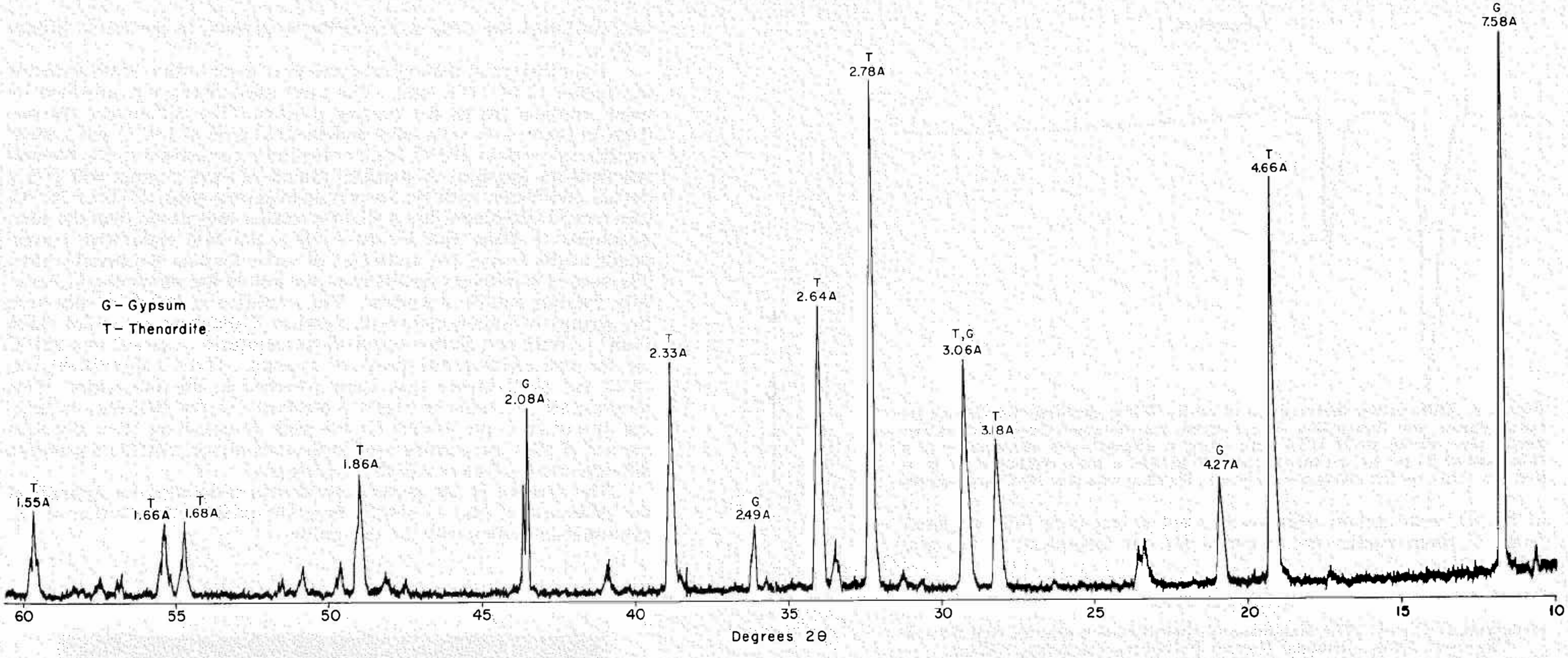

Figure 3. X-ray diffractogram of material from cavity filling showing diffraction maxima for both thenardite and gypsum. Pattern was obtained from hand-picked sample run on a Siemens Crystalloflex IV X-ray unit using CuK α radiation at a setting of 35kv and 18 ma. Scale factor setting is 1×10^5 cpm.

The differential thermal data for pure thenardite give a complex endotherm with the main peak at about 275°C. This endotherm is actually composed of at least two and probably three separate endotherms representing a complex polymorphic transition.

The thermogram (fig. 4) gives a double endotherm for thenardite with peak temperatures at 280°C and 290°C respectively. These temperatures are higher than those of this reaction in pure thenardite at 275°C and must result from interaction with gypsum.

Mirabalite ($Na_2SO_4 \cdot 10H_2O$) and other soluble salts were not detected from either the X-ray diffraction or differential thermal analysis data.

Thenardite associated with gypsum in western Oklahoma is a ground-water deposit. The deposition is a temporal phenomenon occurring with the effluence of ground water at the outcrop where precipitation occurs as a result of evaporation. The current formation of thenardite can be demonstrated by its encrustation of quarry faces

where operations have been suspended for periods of a few weeks to a few months.

Solubility data show that thenardite is about 200 times more soluble than gypsum (Hodgman, 1959, p. 554, 658). Consequently, the ground water must contain about 2,000 times as much Na_2SO_4 as $CaSO_4$ in solution because the ratio of the precipitated species is about 10:1.

The presence of thenardite is a potentially serious problem for the gypsum industry in western Oklahoma, particularly in the production of high-quality gypsum plaster. No easy method of control has been found. The lack of thermal decomposition of Na_2SO_4 up to a temperature of about 900°C precludes heating as a possible method. Owing to its high solubility, sample washing would be a possible, though by no means easy, solution to the problem. Lowering of the ground-water table and methods of controlling vadose water movement are other, but somewhat longer ranged measures. The possibility of the interaction

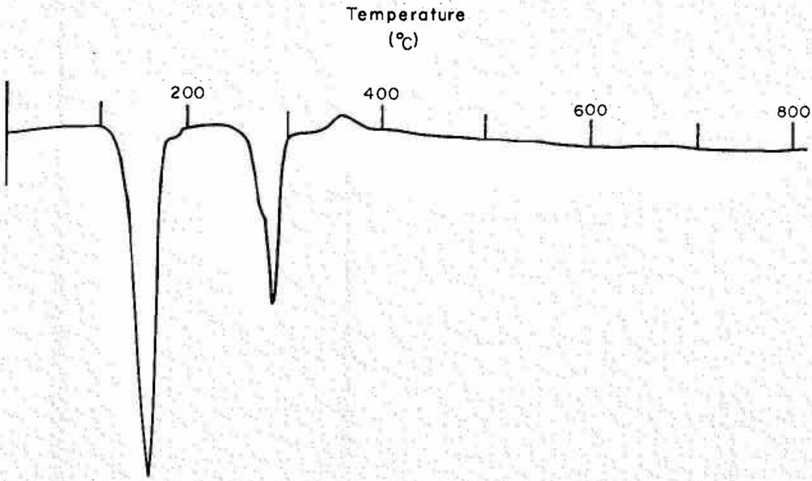

Figure 4. Differential thermogram of cavity filling showing endotherms for both gypsum and thenardite. Thermogram was obtained from a Stone Dynamic Gas Model 13-M DTA unit using a nitrogen gas atmosphere at a flow rate of 25 ml/hr, an inconel sample holder, a scale setting of 80 μ v, and α Al_2O_3 as the reference material. Heating rate was 10°C per minute.

of Na_2SO_4 with certain additives has not as yet been fully explored. Some of these studies are proposed for our laboratory in the near future.

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Schizodus insignis Drake, 1897

Carl C. Branson

In his report on the coal fields of Indian Territory, Drake described a new species of *Schizodus* as *S. insignis* (1897, p. 406, pl. 9, fig. 7). The species was given as from a hard Permian sandstone along the McDermitt-Chelsea road five miles east of McDermitt. It is here suspected that for Chelsea was meant Checotah. A list of fossils found at the locality (p. 396-397) contains the names of no diagnostic species even if the identifications in the list were dependable. The town of McDermitt is shown on the geological map (pl. I, p. 330-331). On the

Wewoka quadrangle topographic map (1896) the town (spelled McDermott) is shown at NE edge sec. 21 and NW edge sec. 22, T. 11 N., R. 10 E. The locality of the fossil was near the site of the present village of Pharoah (spelled thus in error for Pharaoh) in Okfuskee County, probably in sec. 21, T. 11 N., R. 11 E. The area is underlain by the Wewoka Formation, Marmaton Group, Desmoinesian.

Dr. Myra Keen kindly provided a plaster cast of the holotype and single known specimen, which is numbered 814 in Stanford University paleontology type collection. The plastoholotype is OU 5056 in The University of Oklahoma paleontology collection.

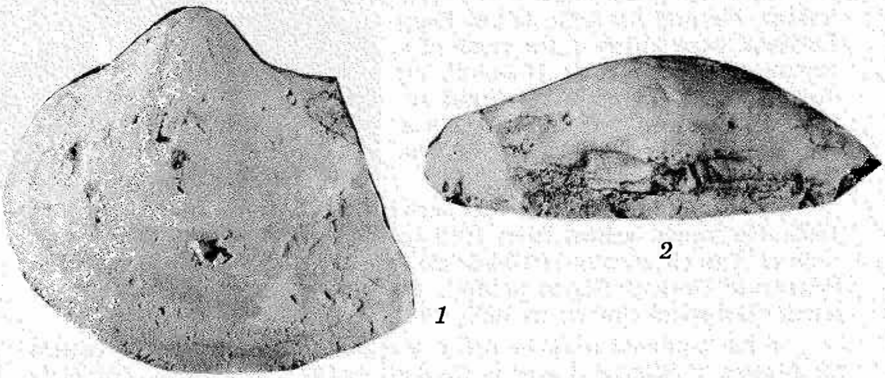

Figure 1. "Schizodus insignis." **Lateral view of the plastoholotype.**
Figure 2. Dorsal view of same specimen as figure 1.

The specimen is a cast of the left valve which is 5 cm high and 6 cm long with some of the posterior end broken away. The anterior adductor scar is in the pallial line in the upper anterior area and the posterior adductor scar is below the hinge behind the umbonal area. The dentition consists of a distinct linear tooth and adjacent socket on the anterior side of the area beneath the beak and of a low rounded raised area on the posterior side.

The species lacks the characteristic oblique posterior ridge and does not appear to have the dentition of *Schizodus*. It must be regarded as unrecognizable unless and until topotype material which shows generic and specific characteristics is obtained.

Reference Cited

Drake, N. F., 1897, A geological reconnaissance of the coal fields of the Indian Territory: Amer. Phil. Society, Proc., vol. 36, p. 326-419. Also issued in 1898 as Leland Stanford Junior University, Contribution to Biology from the Hopkins Seaside Laboratory, vol. 14, p. 326-419. This is a reprint with new title page with the word territory misspelled and with a one-page comment.

A. Rodger Denison

1897-1962

With the death of Dr. Rodger Denison, the science of geology lost a man who has given much to the profession. He and his wife, Maud Espy Denison, were killed in the crash of a commercial airplane at Honolulu on July 22. He had actually passed retirement age and was traveling on a final mission for his company at the time of the tragedy.

Albert Rodger Denison was born near Oklahoma City on June 7, 1897. He taught school from 1913 to 1921 and studied geology part time at The University of Oklahoma, where he earned the Bachelor of Science in Geology degree in 1921. He worked part time for the Oklahoma Geological Survey in 1920, 1921, and 1922.

In his graduate work he had a teaching fellowship and he earned his Master of Science degree in Geology in 1925. His thesis, *The Robberson Field, Garvin County, Oklahoma,* was published in 1923.

Denison went to work for Amerada Petroleum Corporation as geologist in 1923 and rose rapidly, becoming district geologist in 1925, division geologist in 1927, chief geologist in 1937, and vice-president in 1950.

His many services to his country and to his fellow geologists include his work as member of the Board of Directors of the Community Chest (1955-1958), as secretary-treasurer of the American Association of Petroleum Geologists (1929-1930) and later as president of the Association (1943-1944), as a councilor of the Geological Society of America (1954-1957), as member of the Military Petroleum Advisory Board, and chairman of its Production Panel, as director, chairman of the finance committee, and member of the executive committee of American Geological Institute, and as chairman of the advisory committee of Research Project 51 for the American Petroleum Institute. In 1952 he was awarded an honorary Doctor of Science degree by South Dakota School of Mines.

Denison helped students and geologists in many ways. He was representative for geology in The University of Oklahoma Career Conference, lecturer to classes and to public meetings, and he arranged grants to help students in graduate work.

In college Rodger joined Kappa Alpha social fraternity and Sigma Gamma Epsilon, honorary Earth Science fraternity. He was a Mason, a member of the American Geophysical Union, of the Canadian Institute of Mining and Metallurgical Engineers, and a member of the Tulsa Club.

On October 8, 1929, Maud Espy and Rodger Denison were married. They were a devoted couple through the 33 years of their marriage, and it is certain that had they a choice they would have chosen to go together. Their daughter, Cordelia Ann, now resides in Evanston, Illinois. Their son, Rodger Espy, received his bachelor's and master's degrees in geology from The University of Oklahoma and is now working on his doctorate at the University of Texas.

Rodger Denison's life was a busy and productive one. He was especially known to geologists in general for his able and numerous services to the professional societies and to individual geologists.

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1923. The Robberson Field, Garvin County, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 7, p. 625-644.

1926. Early Pennsylvanian sediments west of the Nemaha granite ridge: Amer. Assoc. Petroleum Geologists, Bull., vol. 10, p. 636.

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1943. Our work in the war, a review of work that can and is being done by geologists and geophysicists: Tulsa Geol. Soc., Digest, vol. 11, p. 31-33.

1944. Deeper drilling prospects in the Mid-Continent: Amer. Inst. Mining Engineers, Tech. Publ. 1650, Petroleum Technology, vol. 6, no. 6, 8 p.; reprinted in Oil Weekly, vol. 112, no. 8, p. 20-26, and in Natl. Oil Scouts and Landmen's Assoc., Yearbook 1944, vol. 14, p. 797-802.

1944. A challenge to geology: Oil and Gas Jour., vol. 42, no. 46, p. 66-68, 82; Amer. Assoc. Petroleum Geologists, Bull., vol. 28, p. 897-901; Spanish translation in Bol. Minas y Petroleo, vol. 15, no. 7, p. 41-44.

1945. William Edwin Wallace—recipient of President's award: Amer. Assoc. Petroleum Geologists, Bull., vol. 29, p. 469-470.

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—C. C. B.

Publications from the 21st International Geological Congress

Parts XXIII-XXVI of the *Report of the Twenty-first Session, Norden, 1960* (printed in 1961), have been distributed to persons registered with the International Geological Congress that was held in Copenhagen in 1960.

Part XXIII, *Proceedings of the International Association of Sedimentology,* includes the following papers in English.

Francis P. Shepard: *Deep-sea sands*

F. J. Faber: *Size and shape analysis of sand grains*

A. H. Bouma and D. J. G. Nota: *Detailed graphic logs of sedimentary formations*

H. G. Goodell and D. S. Gorsline: *A sedimentologic study of Tampa Bay, Florida*

Parker D. Trask: *Sedimentation in a modern geosyncline off the arid coast of Peru and northern Chile*

Joseph R. Curray: *Tracing sediment masses by grain size modes*

V. S. Yablokov, L. N. Botvinkina, and A. P. Feofilova: *Detailed paleogeography during Middle Carboniferous in the Donetz basin*

Carmina Virgili: *The sedimentation of the Permotriassic rocks in the Noguera Ribagorzana Valley (Pyrenees-Spain)*

Part XXIV, *Proceedings of the International Committee for the Study of Clays,* includes the following papers in English.

Edward C. Jonas: *Mineralogy of the micaceous clay minerals*

A. Slatkine and L. Heller: *A petrological study of the flint clay from Makhtesh Ramon, Israel*

Part XXV, *International Subcommission on Stratigraphic Terminology, Stratigraphic Classification and Terminology,* is in English and is edited by Hollis D. Hedberg.

Part XXVI, *Proceedings of Section 1-21, Supplementary Volume,* includes the following papers in English.

Leonard F. Herzog: *Geological age determination by X-ray fluorescence Rb/Sr ratio measurements in lepidolite*

Francis P. Shepard: *Submarine canyons of the Gulf of California*

M. I. Faris: *The Cretaceous System of Egypt and its relation with the Eocene sediments*

John S. Stevenson: *Origin of quartzite at the base of the Whitewater Series, Sudbury basin, Ontario*

J. R. Harpum: *Granitic and metamorphic associations in Tanganyika*

H. Sorensen (editor): *Symposium on migmatite nomenclature*

Anna Hietanen: *Superposed deformations northwest of the Idaho batholith*

E. S. Simpson: *A ground-water mechanism for the deposition of glacial till*

Carlos Ruiz F. and Pierre Saint-Amand: *Observations concerning the Chilean earthquakes of May 1960*

—L. J.

Roland LeRoy Clifton

1884 - 1962

A well-known Oklahoma geologist, Roland L. Clifton, passed away on July 27, 1962. He was a long-time resident of Enid and he died in the hospital there after a long illness.

Roland, son of B. F. and Anna Clifton, was born in Stafford, Kansas, on May 13, 1884, and was raised near Freedom, Oklahoma. He taught in various schools from 1901 to 1908 and was a school principal from 1909 to 1911. In 1913 he and Luellen Chesnut were married in Alva. The first bachelor's degree awarded by Northwestern State Teachers College was awarded to Roland in 1920. He served as Superintendent of Schools at Shattuck, at Kingfisher, and at Marlow. He took some course work at the University of Kansas, then came to The University of Oklahoma, where he earned the Master of Science degree in geology in 1925. His thesis was *Areal extent and stratigraphy of the Whitehorse sandstone.*

He worked with Oklahoma Geological Survey and wrote Bulletin 40-A on oil and gas in Woods, Alfalfa, Harper, Major, Woodward, and Ellis Counties (1926), and Bulletin 40-Y on oil and gas in Harmon, Tillman, Jackson, and Greer Counties (1927).

Clifton joined Champlin Oil and Refining Company about 1926 and rose to be its chief geologist, a position from which he retired in 1948. He then became an independent producer and continued in that career the rest of his life.

Clifton was actively interested in scientific matters and published a number of papers on Permian stratigraphy and fossils. He led organized field trips in northwestern Oklahoma, one of which was for Oklahoma Academy of Science.

He served as first lieutenant in the Officer Reserve Corps, State Militia. He was a Mason, an Odd Fellow, and a member of Modern Woodmen of the World. He belonged to Pick and Hammer and Sigma Gamma Epsilon geological societies. His professional societies were American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, Society of Economic Geologists, American Institute of Mining, Metallurgical and Petroleum Engineers, and Oklahoma City Geological Society.

Clifton is survived by his widow, by a son, Roland L. Clifton, Jr., by a daughter, Mrs. John Collin, and by three grandchildren.

—C. C. B.

Type Specimens of Two Oklahoma Mississippian Brachiopods

Carl C. Branson

In 1897 N. F. Drake published an account of the coal fields of Indian Territory, and in the report he described two new species of brachiopods and figured one other species. His figues are artist's drawings. Through the courtesy of Dr. Myra Keen I have been lent the type specimens, which are in the paleontology type collection of Stanford University. Photographs of the specimens were taken by William H. Bellis.

Kozlowskia adairensis (Drake), 1897, new combination
Plate I, figures 1-6

1898. *Productus (Marginifera) adairensis* Drake: Amer. Phil. Soc., Proc., vol. 36, p. 402-403, pl. 9, figs. 1-3.
not 1915. *Productus adairensis* Drake: Girty, U. S. Geol. Survey, Bull. 593, p. 50, vol. 3, fig. 6.
1915. *Marginifera adairensis* Drake?: Snider, Okla. Geol. Survey, Bull. 24, p. 84-85, pl. 4, figs. 12-14.
1935. *Eomarginifera aff. adairensis* (Drake): Hernon, Jour. Paleontology, vol. 9, p. 679.
not 1936. *Productus adairensis* Drake: Croneis, Ark. Geol. Survey, Bull. 3, p. 64, 70, pl. 18, figs. 3, 4.
1938. *Marginifera adairensis* Drake: Sutton, Jour. Paleontology, vol. 12, p. 561.
1960. *Inflatia adairensis* (Drake): Muir-Wood and Cooper, Geol. Soc. America, Mem. 81, p. 227.

Each of Drake's two type specimens is labeled "syntype." Stanford University 818 is labeled "Boston Formation, L. Carbon., five

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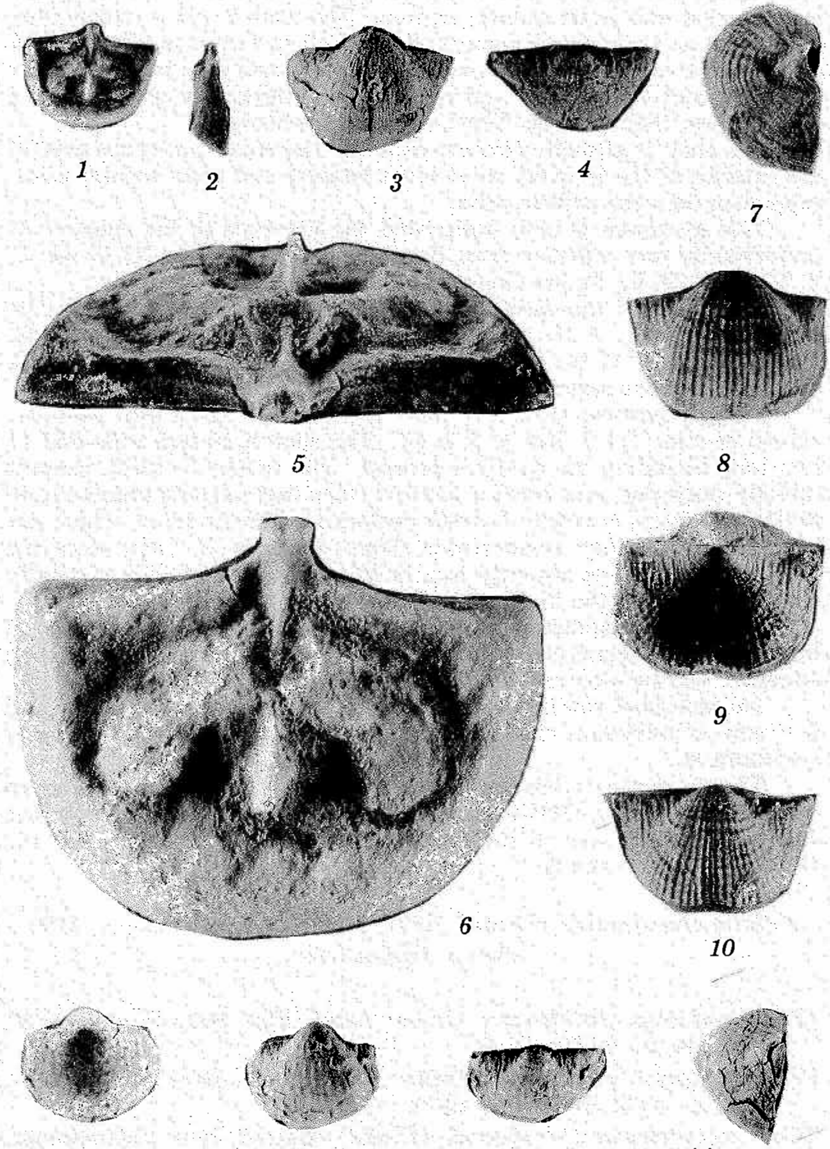
Explanation of Plate I

Figues 1-6. Kozlowskia adairensis **(Drake)**
1. **Interior of brachial valve, the paratype, Stanford 819, x1.**
2. **Laterial view of same paratype, x1.**
3. **Pedicle valve of holotype, Stanford 818, x1.**
4. **Posterior view of same specimen, x1.**
5. **Posterior view of paratype, x4.**
6. **Interior of paratype, x4.**

Figures 7-10. Inflatia cherokeensis **(Drake), holotype, Stanford 815, x1.**
7. **Lateral view.**
8. **Pedicle valve.**
9. **Brachial valve.**
10. **Pedicle valve viewed from point posterior of center.**

Figures 11-14. Shell figured by Drake as "Productus pertenuis," **Stanford 813, x1.**
11. **View of brachial valve.**
12. **View of pedicle valve.**
13. **Posterior view.**
14. **Lateral view.**

Plate I



miles southeast of Adair, Oklahoma." The specimen is a pedicle valve and is the original of Drake's plate 9, figures 1 and 3. The specimen is 22 mm wide, 18 mm long, and 10 mm high. The auricles are well developed and are upturned near the outer corners. The posterior margin is thickened and is irregularly nodose. The shell bears a narrow median sinus on the anterior slope, and the shell surface is marked by fine plications, about 20 to a centimeter. The plications tend to be irregular in width, and to bifurcate and rejoin. The interspaces are sharp and are narrower than the ribs. The beak area is reticulate.

The shell is strongly concavo-convex. The small preserved area of the exterior of the brachial valve bears broader and more regular plications than does the pedicle valve.

This specimen is here designated the holotype of the species. It undoubtedly was collected from the Fayetteville Shale in NE¼ sec. 7, T. 22 N., R. 20 E., Mayes County.

Specimens of the species have been collected from the Hindsville Limestone in sec. 2, T. 16 N., R. 23 E.; sec. 29, T. 15 N., R. 22 E; NE¼ sec. 25, T. 17 N., R. 22 E.; along Park Hill Creek near Park Hill; and about 5 miles east of Vinita.

Drake's syntype (Stanford 819) is a brachial valve with well-preserved interior (pl. I, figs. 1, 2, 5, 6). The shell is 18 mm wide and 14 mm long including the cardinal process. The process is bifid, extends directly posterior, and bears a median ridge that extends anteriorly to divide the deep, centrally located posterior adductor scars, which are bounded by a sharp semicircular ridge. In front of these scars the median septum rises abruptly to a height of 2 mm and ends vertically about 2 mm from the inner edge of the anterior marginal rim.

The anterior adductor scars are elevated, flat, kidney-shaped, and lie near the marginal rim. Each is connected to the rim of a posterior adductor scar by a narrow ridge.

The marginal rim is sharply elevated above the visceral cavity and is 6 mm in maximum height. Its surface is marked by small irregular crenulations.

The specimen is labeled "'Boone' formation, L. Carbonif., seven miles east of Adair, Oklahoma." The locality would seem to be in the Hindsville Limestone on the line between secs. 22 and 27, T. 23 N., R. 20 E., Mayes County.

Inflatia cherokeensis (Drake), 1897, Muir-Wood and Cooper, 1960

Plate I, figures 7-10

1897. *Productus cherokeensis* Drake: Amer. Phil. Soc., Proc., vol. 36, p. 404, pl. 9, figs. 4, 5.

1915. *Productus cherokeensis* Drake: Snider, Okla. Geol. Survey, Bull. 24, p. 80-81, pl. 3, figs 22-24.

1938. *Dictyoclostus cherokeensis* (Drake): Sutton, Jour. Paleontology, vol. 12, p. 563.

The holotype of *Productus cherokeensis* (Stanford 815) is a fine specimen with conjoined valves. It is 26 mm wide, 14 mm long, and

15 mm high. The shell is globose to the extent that it is almost semicircular in lateral outline. The beak curves over the hinge line. The ears are small but distinct and are separated from the body of the shell by a groove. Each ear bears a stout central spine, which is near the hinge adjacent to the beak on each side; and two other small spines are on each side of the beak, each slightly farther away from the hinge than the one next nearer the beak. The shell bears a distinct sinus, which extends from the umbonal slope to the front margin and which bears five plications on its slope. The shell is uniformly ornamented by even, rounded, uniform plications, 18 to 20 on each half of the shell. Three spines have developed on three of the central plications near the anterior end of the shell, and a single spine is at the preserved anterior margin of the shell at one side of the sinus. The shell is reticulate in the umbonal region. The exterior of the pedicle valve is reticulate throughout.

A related specimen from Ringgold, Georgia, is more than 35 mm wide and has two stout spines on the ear.

Two specimens collected by Eaton from the "Mayes lms," Vinita, Oklahoma, are typical. One is 29 mm wide, the other 33 mm wide. Each has three small spines diverging in position from the hinge from the beak outward, and each has one or two stout spines on each ear. One displays three spines near the anterior margin.

A large specimen with trail is from the Fayetteville, 2 miles south and 3 miles east of Adair, Mayes County. It is 38 mm long. One spine is discernible on the anterior slope. Four specimens from the Fayetteville, 3 miles east and 2 miles south of Adair, belong to the species.

A specimen collected by R. L. Lauderback from the Hindsville Limestone in sec. 30, T. 15 N., R. 24 E., Adair County, is entirely typical. Another specimen is from the Hindsville in SE¼ sec. 23, T. 15 N., R. 25 E. Two specimens are from the Hindsville in NE¼ sec. 35, T. 16 N., R. 25 E. Specimens which are conspecific or closely related occur in the Pitkin near Braggs, Muskogee County.

Inflatia inflata (McChesney), 1860, Muir-Wood and Cooper, 1960

1915. *Productus inflatus* McChesney: Snider, Okla. Geol. Survey, Bull. 24, p. 78, 79.
1960. *Inflatia inflata* (McChesney): Muir-Wood and Cooper, Geol. Soc. America, Mem. 81, p. 227, pl. 55, figs. 1-15.

Snider (1915, p. 80-81) reported that at the type locality of *Inflatia cherokeensis* are large numbers of *I. inflata,* a species not reported by Drake. Snider thought that Drake did not differentiate the two species and that he had both forms in his collection. Muir-Wood and Cooper (1960, p. 389, pl. 55, figs. 1-15) identified *I. inflata* from NE¼ sec. 7, T. 22 N., R. 20 E., a locality which is also the type locality for *Kozlowskia adairensis.* There is perhaps no real difference between *I. inflata* and *I. cherokeensis,* but *I. cherokeensis* appears to have coarser plications, more pronounced reticulation, a shorter trail, and longer auriculations. It would seem that Drake's species should stand pending more study.

Plate I, figures 11-14
"Productus pertenuis Meek"

1897. *Productus pertenuis* Meek: Drake, Amer. Phil. Soc., Proc., vol. 36, p. 405, pl. 9, figs 8-10.

Drake noted the species from the several localities here listed.

Lower Coal Measures:

Four miles north of Vinita (probably four miles northeast, in the Fayetteville)

One mile south of Muskogee (probably Spaniard Limestone)

Upper Coal Measures:

Cavanoil group, McClellan ford on Verdigris River (locality unknown)

Poteau group, six miles west of South Canadian (probably Boggy Formation near Indianola, Pittsburg County).

Permian division:

Upper bed of sandstone four miles west of McDermitt (probably Seminole Formation at Okemah).

Pawhuska sandstone, five miles west of Cushing (probably in Council Grove Group, in Payne County).

Curiously, Drake chose to figure a specimen of "The same or a nearly related species . . . in the Lower Carboniferous limestone, Boston group (St. Louis-Chester), five miles southeast of Adair." The specimen is number 813 at Stanford University and is here figured (pl. I, figs. 11-14). The preservation is poor and the species is not determinable. The specimen is from Fayetteville Shale in NE¼ sec. 7, T. 22 N., R. 20 E., Mayes County. It is probably a *Cancrinella.*

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Muir-Wood, Helen, and Cooper, G. A., 1960, Morphology, classification and life habits of the Productoidea (Brachiopoda): Geol. Soc. America, Mem. 81, 447 p., 135 pls.

Snider, L. C., 1915, Paleontology of the Chester group in Oklahoma: Okla. Geol. Survey, Bull. 24, pt. 2, p. 67-122, pls. 3-7.

Microcrinoids of the St. Joe Group

Harrell L. Strimple*

Clarification is needed concerning the location of the horizon that contains the microcrinoid fauna described by Strimple and Koenig (1956) from the St. Joe Group. Huffman (1958) stated that the specimens came from the "green shaly phase" of the St. Joe Group northeast of Tahlequah, Oklahoma. Starke (1961) stated that Strimple and Koenig correlated the "upper limestone unit" (St. Joe) with a shale at the base of the Welden Limestone near Ada, Oklahoma, on the basis of microcrinoids. The microcrinoids are from neither of the above-mentioned units of the St. Joe Group but are from thin shale lentils in the lower limestone unit. According to both of the above-mentioned authors, the limestone unit is Kinderhookian rather than Osagean in age.

The St. Joe microcrinoids are like those of the pre-Welden shale, but the faunas are far from identical. Only one species, *Passalocrinus triangularis* Peck, is common to both formations. This species is rare in both formations, but an undescribed species of *Passalocrinus* is prolific in the pre-Welden shale.

Huffman did not report on the exact area involved here, which is south of Eagle's Nest fishing camp on the Illinois River in NW cor. sec. 24, T. 18 N., R. 22 E., Cherokee County, Oklahoma. Starke reported a maximum thickness of six and one-third feet for the soft, green, calcareous shale at the same location. On May 22, 1962, I revisited the exposure to collect new shale samples and to renew observations. Little change had taken place since I first visited the exposure with Dr. L. R. Laudon in March 1939, except for the fresh exposures created by excavation into the bluffs by the State Highway Department about 0.1 mile north of the natural wash that is the type locality of the microcrinoids. In the wash, the basal member (equivalent of the Compton of Missouri?) consists of about 6 to 8 feet of limestone. The microcrinoids are from shale lentils in the upper 4 feet of this unit. Above this, approximately 25 feet represents the green shaly zone, of which the upper 6 feet forms a shelf of exposed shale under the 60- to 70-foot bluff (bioherm). Limestone beds occur in the lower part of the green, shaly zone which Starke apparently thought represented the basal limestone unit. I did not examine the fresh exposures to the north because of the difficult terrain and the obvious contamination of the exposures from higher Reeds Spring and Keokuk Formations.

Both Huffman and Starke cited correlation of the upper limestone unit of the St. Joe with the Fern Glen of eastern Missouri (Moore, 1928), the New Providence of Kentucky and Tennessee (Butts, 1922), and the Lake Valley of New Mexico (Weller, 1909). Neither applied the terms Compton, Northview, and Pierson, but they considered the equivalents of those units to be present in northeastern Oklahoma.

The most prolific microcrinoid in the basal St. Joe is *Kallimorphocrinus angulatus* Strimple and Koenig. *Allagecrinus sculptus* Strimple and Koenig is rather scarce in the St. Joe and specimens are smaller than the Lake Valley specimens of equal development. *Lampadoso-*

*State University of Iowa, Iowa City

crinus minutus (Peck), rare in the St. Joe, is typical of the Fern Glen Formation of Missouri. *Passalocrinus triangularis* Peck is rare in the St. Joe. *Trophocrinus brevis* Strimple and Koenig and *T. bicornis* Strimple and Koenig are both restricted to the St. Joe. The former is the more common but neither is prolific. The genus *Trophocrinus* has not been reported from the Lake Valley formation but is present in the Fern Glen and pre-Welden units.

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Siliceous Shale in Lower Part of Tenmile Creek Formation, Atoka County, Oklahoma

William D. Pitt and Richard L. Boone

A stratum of siliceous shale, 84.5 to 90 feet thick, was discovered by Richard L. Boone while mapping the Bruno and Lane quadrangles of south-central Atoka County. This siliceous shale is the thickest bed known in the Ouachita Mountains, exceeding by 10 to 15 feet the reported maximum thickness of siliceous shales in the Black Knob Ridge

Table I.—Measured Section of Siliceous Shale Bed in Tenmile Creek Formation, Atoka County, Oklahoma
(NW¼ SE¼ NW¼ sec. 24, T. 2 S., R. 11 E.)

	Thickness (feet)
Shale, blue-gray to black; beds 1 to 6 inches thick; possibly five feet more above measured section	30.5
Covered	1.0
Shale, black, siliceous, platy; weathers brown	0.5
Covered	3.0
Shale, blue-gray to black, silty; non-resistant in half of interval	3.5
Shale, blue-gray to black; mostly siliceous; thin to massive beds up to one foot thick	22.0
Shale, blue-gray to black; siliceous and locally silty; well fractured; beds 1 to 4 inches thick; weathers light gray, brown, or red	36.0

area (Hendricks and others, 1937, p. 12). The outcrop is about 25 yards northeast of State Highway 7 at a point about 0.4 mile southeast of the outcrop of the top of the Arkansas Novaculite on Black Knob Ridge (NW¼ SE¼ NW¼ sec. 24, T. 2 S., R. 11 E.). Part of this section is pictured in figure 1. Only a small part of the 84.5-to-90 feet of siliceous shale is locally silty and nonsiliceous, as shown in the columnar section (table I).

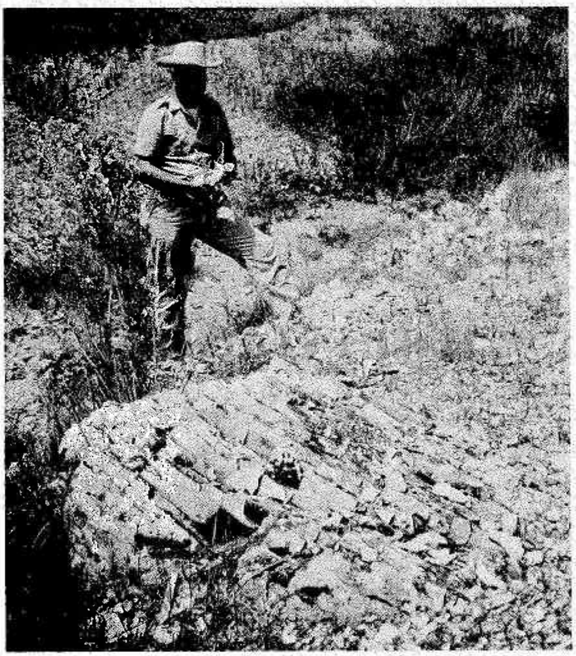

Figure 1. Exposure of siliceous shale bed in Tenmile Creek Formation at NW¼ SE¼ NW¼ sec. 24, T. 2 S., R. 11 E., Atoka County, Oklahoma.

This siliceous shale is approximately 1,100 to 1,300 feet stratigraphically above the top of the Arkansas Novaculite and is therefore a hitherto unrecognized siliceous shale bed above the lower siliceous shale bed of Harlton. The stratigraphic position of the lower siliceous shale of Harlton was described only as being "near the base" (1938, p. 868). The thick siliceous shale also is probably stratigraphically higher than the siliceous shale that Laudon (1959) found 850 feet (stratigraphically) above the Arkansas Novaculite on Dry Creek southwest of the Potato Hills (Cline, 1960, p. 33). The lower part of the Tenmile Creek Formation especially needs to be zoned, described,

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