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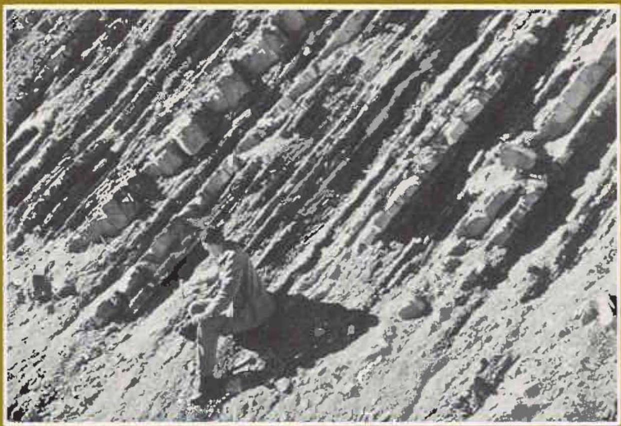

OKLAHOMA GEOLOGY NOTES

VOLUME 28, NUMBER 1 FEBRUARY 1968

Cover Picture

Interbedded Sandstones and Shales, Lower Wildhorse Mountain Formation

The Wildhorse Mountain Formation (Late Mississippian) of the Jackfork Group attains thicknesses greater than 3,500 feet in the central and southern Ouachita Mountains and is composed of interbedded shales and sandstones. The sequence pictured is in the lower part of the Wildhorse Mountain Formation along Big Cedar-Octavia road on the north face of Kiamichi Mountain, LeFlore County.

The shales are laminated and dark gray to black, alternating with sandstones that vary in composition from white, firmly cemented, very fine-grained orthoquartzites to gray, poorly sorted, massive graywackes. The graywackes range from a few inches to about 20 feet in thickness, whereas the orthoquartzites are generally a few inches thick.

Most sandstone-shale contacts are sharp, though some sandstones appear gradational into overlying shales. Soles of the sandstones bear abundant, well-preserved flute, groove, bounce, prod, and load casts. Convolute bedding and other evidences of soft-sediment deformation are also common within these units.

The photograph is from Oklahoma Geological Survey Bulletin 85, *Stratigraphy of the Late Paleozoic Rocks of the Ouachita Mountains, Oklahoma,* by L. M. Cline.

—*P. W. W.*

The Mineral Industry of Oklahoma in 1967*
(Preliminary)

Robert B. McDougal†

Value of Oklahoma's mineral production in 1967 reached $1.1 billion, nearly 6 percent greater than that of the previous record year of 1966, the Area IV Mineral Resource Office of the Bureau of Mines, U. S. Department of the Interior reported. Demand for petroleum was strong throughout the year, although production was stimulated the last half year as a result of the Middle East crisis in June. A general lag in construction activities affected nonmetallic minerals and commodities such as cement, sand and gravel, and stone. Significant gains were reported in value of lime, natural gas, natural-gas liquids, and petroleum. Substantial losses in value were reported in bentonite, coal, helium, lead, sand and gravel, silver, stone, tripoli, volcanic ash, and zinc.

MINERAL FUELS

Coal.—Output of coal decreased more than 5 percent from the previous year's production. Unit-train operation resulting in reduced costs began in January from the Peabody Coal Company operation near Chelsea to a power-generating plant in Kansas City, Missouri. Howe Coal Company, subsidiary of Garland Coal Company, began developing a slope mine near Howe to supply six Japanese steel firms with coal. The coal will be carried by unit train to Port Arthur, Texas, for shipment to Japan. In August, Kerr-McGee Corporation reported that work would begin immediately on a 1,380-foot mine shaft southeast of Stigler. The company announced plans to construct 50 coke ovens for production of metallurgical-grade coke.

Natural gas.—Marketed output of natural gas was 7 percent higher in 1967.

Natural-gas liquids.—Condensable liquids extracted from natural gas at 73 natural-gasoline plants and 5 cycling plants reached a new record of 1,605 million gallons. Service Gas Products Company began operating its 15-million-cubic-foot-per-day refrigerated-absorption Aline plant in Alfalfa County. National Fuels Corporation increased its Madill plant propane capacity by 4,000 gallons per day. Shell Oil Company announced plans to build a 75-million-cubic-foot-per-day refrigerated-absorption plant in Dewey County to produce 42,000 gallons of propane per day and 49,000 gallons of gasoline per day. Scheduled completion date is May 1968.

Yearend storage capacity for LP gases totaled 2,616,000 barrels at 15 underground sites in seven counties.

Petroleum.—Output of 232 million barrels of crude petroleum was

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* This report, U. S. Bureau of Mines Mineral Industry Surveys Area Report IV-215, was prepared December 6, 1967.

† Geologist, U. S. Bureau of Mines, Area IV Mineral Resource Office, Bartlesville, Okla.

TABLE I.—MINERAL PRODUCTION IN OKLAHOMA[1]

MINERAL	1966 QUANTITY	1966 VALUE (THOUSANDS)	1967 (PRELIMINARY) QUANTITY	1967 (PRELIMINARY) VALUE (THOUSANDS)
Clays[2] (thousand short tons)	745	$ 754	745	$ 754
Coal (bituminous) (thousand short tons)	843	4,935	800	[3]
Gypsum (thousand short tons)	785	2,212	745	2,245
Helium (thousand cubic feet)	352,400	12,333	310,000	10,436
Lead (recoverable content of ores, etc.) (short tons)	2,999	907	2,530	708
Natural gas (million cubic feet)	1,351,225	189,172	1,421,000	203,203
Natural-gas liquids:				
Natural gasoline and cycle products (thousand gallons)	576,124	35,715	577,700	36,395
LP gases (thousand gallons)	986,254	44,381	1,027,800	49,334
Petroleum (crude) (thousand 42-gallon barrels)	224,839	654,281	231,600	694,710
Salt (thousand short tons)	[3]	[3]	11	79
Sand and gravel (thousand short tons)	6,040	7,565	5,980	7,414
Stone (thousand short tons)	15,334	17,393	14,947	16,983
Zinc (recoverable content of ores, etc.) (short tons)	11,237	3,259	11,500	3,197
Value of items that cannot be disclosed: bentonite, cement, copper, lime, silver, tripoli, volcanic ash, and value indicated by footnote 3	....	24,484	....	27,036
Total		$997,391	....	$1,052,494

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producer).

[2] Excludes bentonite; included with "Value of items that cannot be disclosed."

[3] Included with "Value of items that cannot be disclosed."

reported in 1967, a gain of 6 percent over that of the previous year. Midwest refinery demand for Oklahoma crude oil was responsible for the increase during the first part of 1967, and shortages created by the Middle East crisis caused additional demand in the latter part of the year. The daily petroleum allowable production was retained at 50 percent of the basic depth-acreage formula through March by the Oklahoma Corporation Commission; the April rate was reduced to 46 percent then reduced to 42 percent for May and June. The allowable was raised to 50 percent for July; however, at a special meeting in

July, it was raised to 54 percent retroactive to July 1 and remained at that level the remainder of the year.

The price per barrel of crude oil was raised 3 to 8 cents by most purchasers in Oklahoma during the year. Other purchasers eliminated the high-gravity penalty for crude oil bought in the Oklahoma Panhandle.

The AAPG Committee on Statistics of Drilling reported in *The Oil and Gas Journal* that 360 exploration wells were drilled in the first 10 months of 1967—off 11 percent from the same period in 1966. Total wells drilled in 1967 were 2,720—17 percent below the corresponding 10 months in 1966.

Thirteen operating refineries had a total daily operating capacity of 425,500 barrels of crude oil and 218,610 barrels of cracked gasoline per day on January 1, 1967, up from a year earlier. Apco Oil Corporation completed a 1,645-barrel-per-day hydrofluoric acid alkylation unit at its Cyril refinery. Catalytic reforming capacity was increased to 41,500 barrels per stream day by Sunray DX Oil Company at its Tulsa refinery.

HELIUM

Marketable production and value of helium extracted from natural gas at the Federal Bureau of Mines Keyes plant was 15 percent below that of 1966.

NONMETALS

Estimated value of nonmetals—cement, clays and bentonite, gypsum, lime, salt, sand and gravel, stone, tripoli, and volcanic ash—produced in 1967 totaled $48 million, down 5 percent from 1966.

According to the Bureau of Business Research, The University of Oklahoma, total construction outlay in Oklahoma in the first 10 months of 1967 was about 15 percent below that of the corresponding period in 1966. The national decline was 1 percent.

Cement shipments in Oklahoma were about 5.3 million barrels, down slightly from 5.4 million barrels in 1966.

METALS

Eagle-Picher Industries, Inc., strip-mined copper ore from the Permian redbeds near Creta in Jackson County. Silver was recovered as a coproduct.

Output of lead in Ottawa County declined 16 percent and the value 22 percent in 1967 from 1966; zinc output decreased 7 percent in quantity and 2 percent in value as compared with 1966. The price of lead at New York remained at 14 cents per pound throughout the year, or one-half cent below the price at which payment is made under the Lead-Zinc Mining Stabilization Program. Zinc prices were 14.5 cents per pound through April 28. The price dropped during May and June, then stabilized at 13.5 cents per pound. Zinc was then eligible for subsidy payment under the Stabilization Program.

Three horizontal-retort zinc plants were operated in 1967. They were American Metal Climax, Inc., at Blackwell, Eagle-Picher Industries, Inc., at Henryetta, and National Zinc Company at Bartlesville.

Tri-State district.—Nearly three-fourths of the lead concentrates and zinc concentrates were produced in the Oklahoma portion of the Tri-State district. The remaining lead and zinc concentrates were produced from ores mined in Missouri and Kansas.

In other developments, Kerr-McGee Corporation announced plans to build a $25-million uranium-conversion plant west of Sallisaw in Sequoyah County. Uranium 308 (U_{308}) from domestic and foreign mills will be converted to uranium hexafluoride (UF_6) in a process by which the refined uranium will first be hydrofluorinated with anhydrous hydrofluoric acid, then fluorinated with elemental fluorine. The plant will be designed to process 5,000 to 10,000 tons of U_{308} annually.

New Theses Added to O. U. Geology Library

The following Master of Science theses and doctoral dissertations were added to The University of Oklahoma Geology Library in November and December 1967:

Master of Science Theses

Geophysical investigation of basement relief conditions in southwestern McClain County, Oklahoma, by John L. Bedwell.

Pleistocene geology of Salt Fork and North Fork of Red River, southwestern Oklahoma, by Philip Jan Cannon.

Geology of eastern Choctaw County, Oklahoma, by Andrew Duarte.

Palynology of the Ozan Formation (Cretaceous), McCurtain County, Oklahoma, by Ralph Archie Morgan.

Petrology of the Hennessey Shale (Permian), Wichita Mountain area, Oklahoma, by David Allen Stith.

Doctoral Dissertations

Brachiopod biostratigraphy of the Viola and "Fernvale" Formations (Ordovician), Arbuckle Mountains, south-central Oklahoma, by Leonard P. Alberstadt.

Micropaleontology of the Fernvale Formation of Tennessee and Oklahoma, by Kenneth V. Bordeau.

—*L. F.*

OKLAHOMA ABSTRACTS

GSA Annual Meeting, New Orleans, Louisiana

November 20-22, 1967

The following are abstracts of papers related to Oklahoma geology presented at the 1967 Annual Meeting of the Geological Society of America and Associated Societies. They are reproduced photographically from the program of the meetings and the permission of the authors and of R. C. Becker, executive secretary of the Geological Society of America, to reproduce these abstracts is gratefully acknowledged.

Oklahoma Geology Notes should not be given as the primary source in citations of or quotes from the abstracts. The correct citation is Geol. Soc. America and Assoc. Socs., 1967 Ann. Mtgs., Program, p. ... Page numbers are given in brackets at the lower right of each abstract.

Carbon-13 Variations among Hydrocarbons in the Ponca City Crude Oil

FERGUSON, WILLIAM S., *Marathon Oil Co., P. O. Box 269, Littleton, Colo. 80120*

We determined carbon-13 values (δC^{13}) for samples of n-hexane, benzene, n-decane, trans-decalin, tetralin, naphthalene, 1-methyl-3-propylbenzene, and n-tetracosane, which were all isolated from their Ponca City reference petroleum by API Research Project 6 personnel. In keeping with previous reports on naturally occurring hydrocarbon mixtures, we found aromatic concentrates from the Ponca City oil to be 1–2 per mil carbon-13 enriched relative to saturated mixtures. This consistency did not extend to single hydrocarbon compounds: trans-decalin, a saturated molecule, was the most carbon-13 enriched compound measured (+9.9 per mil *versus* the NBS #22 oil standard); tetralin, an aromatic, was the least carbon-13 enriched (−4.0); and naphthalene, another aromatic, was intermediate (−0.4).

These three compounds have carbon atom skeletons which can be interrelated formally by hydrogenation-dehydrogenation reactions alone; but, because carbon-13 variation is so large among trans-decalin, tetralin, and naphthalene in the Ponca City oil, we suspect these samples are genetically more distant than a hydrogenation-dehydrogenation relationship. The three compounds possibly are derived from quite different carbon atom source materials containing different levels of carbon-13.

Normal paraffins were among the least carbon-13 enriched compounds measured. Further, they showed a small progressive increase in carbon-13 content from −3.1 per mil for n-hexane to −1.2 per mil for n-tetracosane. In contrast to the speculation for trans-decalin, tetralin, and naphthalene, the source material for normal paraffins in petroleum in the C_6 to C_{24} range evidently contains an almost uniform level of carbon-13. [64]

Curvature of Marginal Folded Belts Flanking Major Mountain Ranges: Accentuated or Caused by Lateral Translation of Epidermal Stratified Cover?

GWINN, VINTON, *School of Geology, Louisiana State University, Baton Rouge, La. 70803*

Arcuate fold belts convex to the craton form the margins of many major orogens. Possible causes of the curvature, among others, are: (1) failure of anisotropic basement during shorten-

ing along inherited tectonic trends; (2) differential basement shortening along strike; (3) bending of formerly straighter fold belts by oroclination (Carey, 1958); and (4) differential shortening along strike of a detached sedimentary cover.

The viability of (1), (2), and (3) in generating fold arcs in regions where deep drilling and geophysics demonstrate nonconcordant, essentially undeformed basement is questioned. Differential longitudinal shortening of the cover, detached along bedding-parallel sole thrust zones, must contribute to the production of typical arcuate kinematic patterns.

Considering an originally straight thin-skinned fold tract, curvature would be generated by subsequent differential shortening and translation along strike above the detachment zone. Salients convex in the transport direction would be approximately bisected by nearly radial zones of culmination along which maximum shortening had occurred above the flat thrusts. Plunge depressions in recesses would mark zones of relative retardation of outward translation and shortening. The curvature, culminations, and depressions bounding the arcs would be generated simultaneously.

Regional attitudes of the detachment zone imposed by patterns of pretectonic basement subsidence would moderately influence the kinematic patterns, as would limited undetected basement involvement.

Application of the dermal shortening hypothesis is permitted by observed patterns of curvature, culmination, and depressions in thin-skinned parts of the Central Appalachian, Ouachita, and the Wyoming-Idaho fold arcs. [87]

Structural Review of the Frontal Ouachita Mountains, Arkansas

MORRIS, ROBERT C., *Geology Div., Northern Illinois University, DeKalb, Ill. 60115*

Current field mapping along an 80-mile strip of the frontal Ouachita Mountains of Arkansas permits a preliminary tectonic appraisal. Not surprisingly there are considerable similarities with the frontal areas of Alberta, the southern Appalachians, and of course, the Oklahoma Ouachitas. The study area consists of east-west-trending "peel" thrusts and folds which connect with mapped structures in Oklahoma. Open, simple folds have developed in Jackfork and Atoka rocks while complicated, often disharmonic folds are present in Stanley and Johns Valley shales. The rocks are cut by numerous high-angle, east-west-trending thrust faults which presumably flatten out to become bedding-plane faults in the incompetent Stanley shales. Two fenster faults, the larger more than 35 miles long, indicate folding of occasional inner (southernmost) bedding-plane faults. A structural comparison of Stanley-Atoka with pre-Stanley rocks may mean that they have been subjected to entirely different forces, suggesting that the former are rootless (allochthonous) and separated from the older by a major décollement. Pre-Stanley rocks display tight, isoclinal folding and high-angle faulting, possibly originating in the basement, and thus suffered little crustal shortening.

The Ouachita Orogeny is postulated to have been triggered by vertical uplift south of the present fold belt. Plates of Stanley-Atoka rocks slid northward along décollements, piling against or overriding blocks of similar age along the frontal Ouachitas. Bedding-plane faults sometimes became folded along the inner margin of the frontal belt. High-angle thrusts developed subsequently on the backs of these folded, bedding-plane thrusts. [156]

Calcispongea (Sphinctozoa) from the Pennsylvanian (Desmoinesian) Pawnee Limestone of Northeastern Oklahoma

TOOMEY, DONALD FRANCIS, *Pan American Petroleum Corp., Research Center, Tulsa, Okla. 74102*

The wavy-bedded lower 6 feet of the Pennsylvanian (Desmoinesian) Coal City Member (=Laberdie) of the Pawnee Limestone, exposed in Nowata County, northeastern Oklahoma, contains abundant calcisponges referred to as *Cystauletes mammilosus* King. The Pawnee specimens are large (up to 12 inches in length) and may be straight, bent, or branching; both calcified and silicified specimens are common. The sponge is cylindrical and is traversed by a relatively large smooth central retrosiphonate spongocoel which appears to have remained open during life. The osculum is polytholosiid, and the filling structures are in part vesicular; no spicules were seen. The wall is perforate and the arrangement of the chambers is glomerate, imparting to the sponge an over-all nodular appearance. Occurring with the cystauletids are a few girtyocoelid-type calcisponges.

Petrologically, the sponge host rock is an algal bound stone primarily composed of crusts of the red alga *Archaeolithophyllum*. Fistuliporid bryozoans, polychaete worm tubes (*Spirorbis*), and encrusting agglutinated and calcareous smaller foraminifers (*Hedraites*, *Plummerinella?*, *Tuberitina*, *Polytaxis*, *Tetrataxis*, *Ammovertella*, and *Minammodytes*) are conspicuously ephiphytic on the surfaces of this alga. A relatively diverse silicified megafauna has also been derived from this interval (rugose corals, prismoporid-fenestellid-ramose bryozoans, and productoid brachiopods). The brachiopod *Crurithyris* is the dominant megafaunal component. Agglutinated hyperamminid foraminifers are also abundant. Significantly, no fusulinids and only rare calcareous mobile-type smaller foraminifers have been found within the sponge horizon. [222-223]

Northern Structural Rim of the Gulf Basin

WOODS, R. D., *Humble Oil and Refining Co., P. O. Box 2180, Houston, Tex. 77001*

The northern rim of the Gulf Basin was initially shaped by Precambrian events that set the pattern for the Llanoria geosyncline, one of three great Paleozoic geosynclines of North America. An Upper Paleozoic orogeny within this geosyncline created a mountain system extending 1300 miles from Alabama to West Texas. Its connection with the Appalachians is conjectural, and its trend in northern Mexico is obscure. Most of the system is now buried beneath 2000 feet or more of post-Paleozoic sediments; only three uplifts, the Ouachita, Marathon, and Solitario, expose 275 miles of the margin. The influence of this structural rim on post-Paleozoic structural trends and sedimentation within the Gulf Basin has been significant. Extensive research in the exposed areas has illuminated many of the stratigraphic problems, but structural interpretations, such as the magnitude of thrusting, are still controversial. The buried part is least known. About one well per hundred square miles has penetrated a few tens or hundreds of feet into the structure. Few fossils other than palynomorphs have been found in the unmetamorphosed sediments. A first approximation of the trend and complexity of the buried elements has been provided by an analysis of the metamorphic facies patterns. These patterns and regional gravity suggest that the Choctaw anticlinorium may be near the principal axis of deformation. Geophysical and limited well data indicate that widespread Paleozoic sediments are beneath Mesozoic sediments, toward the Gulf from this axis. [241]

Oklahoma Academy of Science, 56th Annual Meeting Oklahoma City, Oklahoma

December 1-2, 1967

The following are abstracts of papers related to Oklahoma geology presented at the 56th Annual Meeting of the Oklahoma Academy of Science. Permission of the authors and of Tommy B. Thompson, vice-chairman of Section B (Geology) of the Academy, to print these abstracts is gratefully acknowledged.

Paleoecology of Pennsylvanian Coal Swamps in Oklahoma

WILSON, L. R. School of Geology and Geophysics, The University of Oklahoma, and Oklahoma Geological Survey, Norman, Oklahoma 73069

Coal is one of the three important fuels in Oklahoma and stratigraphic recognition of the seams is important in exploration. A paleoecological understanding of the coal swamps in which the coal was formed is an aid to their stratigraphic identification. Associated with the plant remains that formed the coal are fossil spores and pollen that were derived from them. Because these microfossils are abundant and diagnostic they can be used to determine the history of coal swamps. Certain species of the parent plants that produced the spores and pollen are stratigraphically restricted in the forty or more distinct coal seams of Oklahoma. Therefore certain fossil spores and pollen can be used to identify particular coal seams. Studies show that various microfossil species are also restricted within the seams and occur in definite sequences. They indicate that coal swamps developed through at least three recognizable successional stages. Numerous seams in Oklahoma cover thousands of square miles on the surface or are buried at various depths. All seams differ in thickness over their areal range and commonly certain parts of the normal spore and pollen successional stages are different or are absent at one place or another. These variations from the normal order indicate that geographic and local succession factors also existed during the development of the coal swamps. Evidence from plant fossils indicates that the paleoecology of the Oklahoma Pennsylvanian coal swamps was more closely related to the geomorphic rather than the climatic history of the region.

Preliminary Studies of Opaline Phytoliths from Selected Oklahoma Soils

YECK, RONALD D., and GRAY, FENTON Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma 74074

A study was conducted to determine characteristics of opaline phytoliths in Oklahoma soils, on which vegetation varied as a factor of soil genesis.

Opaline phytoliths are amorphous silica deposited in and around plant cells. They accumulate in soils when plants decay. Grasses accumulate opaline phytoliths in greater quantities than do other plants.

In the present study, opaline was extracted from the 2-5 μ, 5-20 μ, and 20-50 μ fractions of the "A" horizons of soils with tallgrass prairie, shortgrass prairie, and forest vegetation. Opaline was also extracted from roots and tops of various native grasses and trees.

The grass leaves contained 2.22 to 6.27 percent opaline and the tree leaves contained 0.34 to 1.20 percent. Tree and grass roots contained similar quantities.

The largest quantities of opaline from all soils occurred in the 5-20 μ fraction. These quantities were approximately six times as large as those in the 20-50 μ fraction. In other parts of the United States, workers have reported the 20-50 μ fraction to be about equal to that of the 5-20 μ fraction in opaline content, with the 2-5 μ fraction having the least amount.

Among the soils, the largest percent (5.92) occurred in the tall-

grass prairie soil "A" horizon. The forest soil contained 3.98 percent, and the shortgrass prairie soil 2.89 percent. The indication of larger quantities of opaline phytoliths in the forest soil relative to the shortgrass prairie soil may be due to incomplete study of the soil profile; otherwise, it suggests that the forest soil was once covered with prairie vegetation.

Microscopic studies of opaline revealed that opaline in soils is indicative of the general type of vegetation, based on opaline shapes observed in plant extracts.

This investigation indicates that opaline in Oklahoma is similar to, although smaller than, that encountered by other workers. Opaline promises to be a valuable tool in the study of soil genesis.

Geology of the Miami-Picher Lead-Zinc Field, Northeastern Oklahoma and Southeastern Kansas

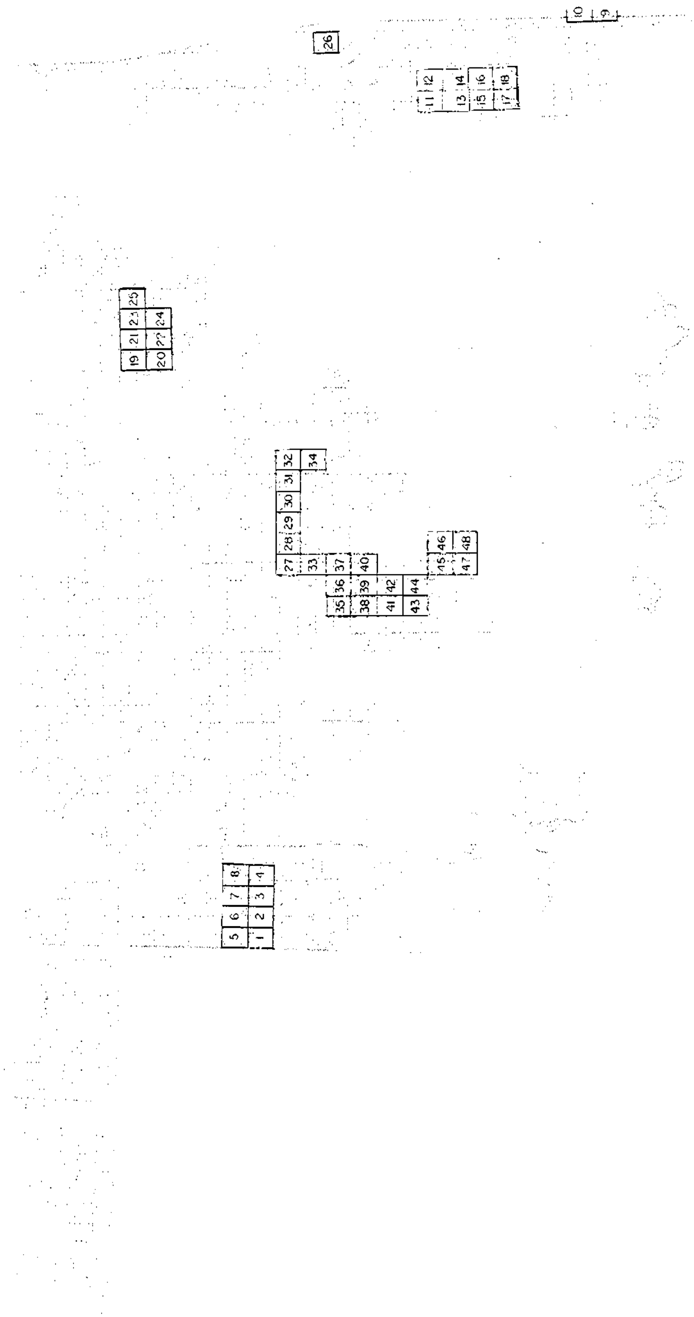
UNDERWOOD, ROGER Department of Geology and Geography, Oklahoma State University, Stillwater, Oklahoma 74074

The area has yielded a large part of the $850 million total production of the Tri-State district. The Mississippian Boone Formation, the major ore-bearing formation exposed, is unconformably overlain by the Pennsylvanian Cherokee Shale on the flank of the Ozark dome.

Sixteen beds in the Boone are designated by letters of the alphabet; of these, six are mineralized to a major degree. The area contains several major faults and disturbed zones. Depositional control is mainly structural, with some stratigraphic control where conditions have been favorable. The most favorable structures are wide and intensely shattered shear zones. Others are openings along bedding planes, crests of anticlines, bottoms of synclines, and circular slumps. The major structural features are the Miami and Bendelari troughs, or grabens, which intersect each other in this area.

The three rock types associated with alteration in this area, dolomite, chert, and jasperoid, are thought to be epigenetic. Fifty-one primary and several secondary minerals are recognized, principally calcite, chalcopyrite, dolomite, galena, marcasite, pyrite, and sphalerite. Sphalerite and galena are the most important. Studies of vacuoles by others have shown the range of temperature of formation to be 52 to 120°C, with a correction of +10°C for pressure. Higher temperatures of mineral deposition are found near the Miami trough, with a decrease as the distance from the trough increases. The greater part of the economic mineralization is concentrated at the intersection of the Miami and Bendelari troughs. This fact and the variation of temperature of formation indicates that the mineralizing solutions were transported along these zones.

Two major hypotheses of source of ore fluids are ground water and hydrothermal origins. The author favors the hydrothermal theory because: (1) the trace elements present, silver, cadmium, copper, barium, arsenic, germanium, gallium, and indium, are typical of hydrothermal deposits; (2) several stages (two in this area) are a characteristic of epithermal deposits; (3) enargite, a copper arsenic sulfide found with some of the district ores, is distinctive of hydrothermal deposits. The main objection to the hydrothermal theory is the absence of a likely parent igneous body in the general area.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New Topographic Maps in Oklahoma

Carl C. Branson

Modern topographic maps are not only useful but are necessary to highway planners, geologists, irrigation- and drainage-project engineers, tax assessors, pipeline and transmission-line surveyors, and many others. The 1:24,000 scale is currently the adequate form in 7½-minute quadrangles. Complete coverage of the State would require 1,213 sheets. Of this number 277 are now available in published form, 32 issued since July 1967. Two hundred twenty-four quadrangles are in preparation, and 44 are authorized. The 545 quadrangles would add to the equivalent of 321 7½-minute quadrangles already published at the 1:62,500 scale.

A new service is now available: interim revision, in which changes in culture are shown in purple without otherwise modifying the map. The new type of map will help to keep reasonably current in expanding metropolitan areas.

The Geological Survey prefers to issue reports in county units and would like to use topographic bases. The Custer County report will be on a 1:62,500 scale on such a base. Other counties with available 1:62,500 bases are Beckham, Washita, Caddo, Comanche, and Cotton. Counties with complete coverage at 1:24,000 are Oklahoma, Cleveland, and Tulsa. When the maps currently being prepared are published, other counties completely covered at 1:24,000 will be Grant, Kay, McClain, Pontotoc, Coal, and Johnston. Topographic maps issued since July 1967 are listed below; number refers to location on the index map, opposite page.

1. Durham
2. Crawford
3. Roll
4. Roll SE
5. Antelope Hills
6. Antelope Hills NE
7. Roll NW
8. Roll NE
9. Chapel Hill (Ark.)
10. DeQueen NW (Ark.)
11. Leflore
12. Summerfield
13. Blackjack Ridge
14. Leflore SE
15. Whitesboro
16. Muse
17. Honobia
18. Ludlow
19. Hominy
20. Cleveland
21. Hominy NE
22. New Prue
23. Avant NW
24. Avant SW
25. Avant
26. Muldrow
27. Piedmont
28. Bethany NE
29. Edmond
30. Arcadia
31. Luther
32. Wellston
33. Bethany
34. Luther SE
35. Union City
36. Minco NE
37. Mustang
38. Minco
39. Tuttle
40. Oklahoma City SW
41. Pocasset
42. Chickasha NE
43. Chickasha
44. Tabler
45. Bradley
46. Criner
47. Lindsay SW
48. Lindsay

Trace Elements in Carbonates of the Foraker Formation (Lower Permian) in North-Central Oklahoma

Ataolah Mogharabi*

INTRODUCTION

The trace-element study of the Foraker Formation in north-central Oklahoma (fig. 1) was part of a study of the petrology of this formation I made in 1965-1966. The purposes of trace-element analysis of the carbonate rocks were (1) to determine the abundance of some commonly occurring trace elements, (2) to see if these elements provide any information for fuller understanding of the depositional environment, and (3) to determine the relationship of selected trace elements, especially strontium, to the diagenesis of carbonates.

Trace-element analyses were run on 30 carbonate samples of the Foraker Formation from north-central Oklahoma, where seven stratigraphic sections were measured in Osage and Pawnee Counties (fig. 1). The Foraker Formation in these counties consists of limestones interbedded with shales, fine-grained sandstones, and in places, thin beds or nodules of chert. This formation includes the strata above the Admire Shale and below the Johnson Shale. The thickness of the Foraker ranges from 47 feet in northwestern Osage County (sample location 1) to 65 feet in southeastern Pawnee County (sample location 7). The Foraker Formation changes facies southward from limestone to sandstone. This facies change is evidenced by comparing sample location 7, where sandstone is the most prominent rock type, to sample location 1, where limestone predominates.

Trace-element analyses were run according to the semiquantitative spectrochemical methods outlined by Mitteldorf (1957), which permit an accuracy of ±30 percent. The analyses were performed by Kenneth Sargent, graduate student at The University of Oklahoma.

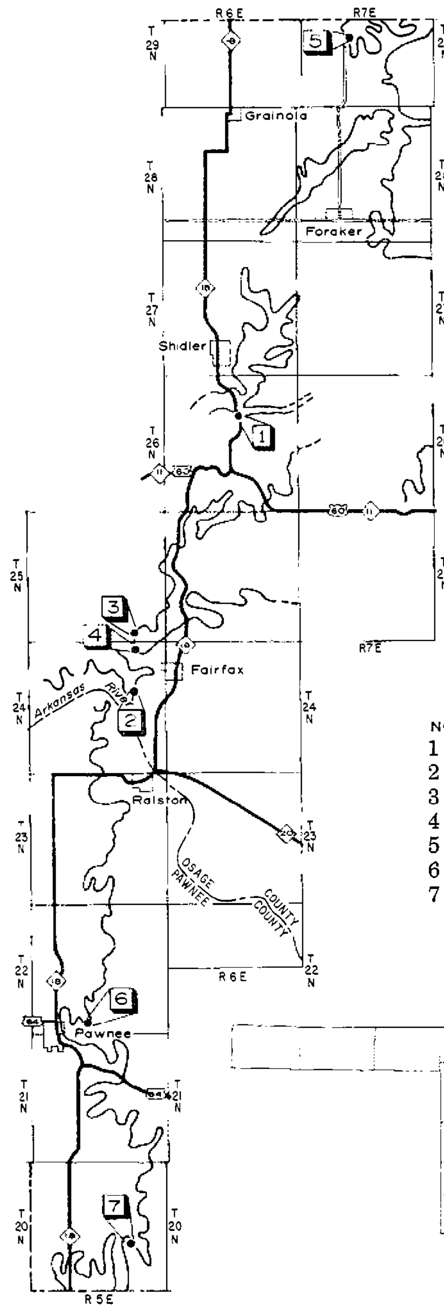
Powdered rock samples (less than 80 mesh) were diluted and thoroughly mixed with spectrographic-grade graphite at a ratio of 1:9 by weight. Five-milligram charges were loaded into a graphite electrode and burned completely in a 5-amp DC arc. Comparisons were made with G standards that were diluted and burned in the same manner as the samples. The instrument used was a Jarrell-Ash, 1.5-meter Wadsworth-grating spectrograph. The spectra were recorded on 35-mm film and compared on a Jarrell-Ash microphotometer.

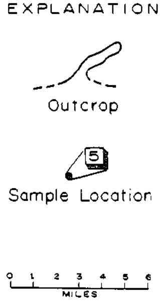
The trace elements selected for analysis were strontium, zirconium, copper, manganese, vanadium, and titanium; the results are listed in table I. Concentrations of copper, vanadium, and titanium are not discussed because the data did not appear significant.

MANGANESE

The manganese content of the 30 carbonate samples ranged from

* Midwestern University, Wichita Falls, Texas.





SAMPLE LOCATIONS

NO.	SEC.	T-N	R-E
1	SW-NW 10	26	6
2	NE-NE 14	24	5
3	SW-SE 35	25	5
4	NW-NE 2	24	5
5	SW-SW 16	29	7
6	NE-SW 33	22	5
7	SW-SE 23	20	5

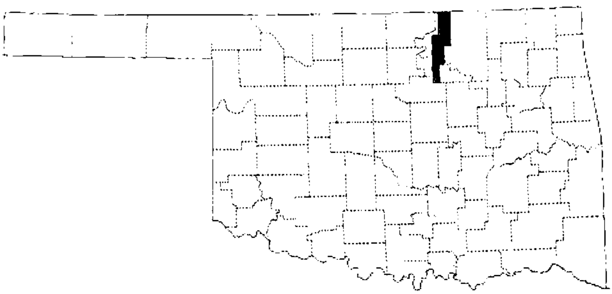


Figure 1. Outcrop map, Foraker Formation, Osage and Pawnee Counties, Oklahoma.

50 to 800 ppm, averaging 240 ppm. An extensive study by Ronov and Ermishkina (1959) on the manganese content of sedimentary rocks demonstrates the significance of this element as a paleoclimate indicator. They reported that the manganese content is greater in carbonate rocks formed in humid climates than in those formed in arid climates. The average manganese content of 3,967 carbonate rock samples thought to have been formed in humid climates was 810 ppm, and the average for more than 6,000 samples from arid climates was 320 ppm. They concluded that manganese would migrate farther and that the migration would last longer in the acid solutions rich in organic matter characteristic of humid climates. Extensive erosion of a manganese-rich

TABLE I.—TRACE-ELEMENT CONCENTRATIONS IN CARBONATES OF THE FORAKER FORMATION

SAMPLE NUMBER[1]	CONCENTRATION[2] (PPM)					
	Ti	V	Mn	Cu	Zr	Sr
1-1	75	50	200	75	nd	200
1-2	50	nd	200	1	nd	400
1-3	50	nd	75	75	nd	400
1-4*	100	nd	350	75	nd	600
1-5*	200	<5	300	75	nd	900
1-6*	25	nd	75	<1	nd	200
1-7*	25	25	75	1	nd	300
1-9*	100	<5	250	50	nd	300
1-10	100	nd	75	1	200	100
1-13*	75	<5	150	1	nd	200
1-14	25	<5	75	<1	nd	200
1-17	10	nd	50	10	nd	300
1-18	75	<5	100	50	nd	700
1-19	100	<5	75	1	nd	400
1-24	50	nd	75	<1	nd	400
1-26	25	10	50	<1	nd	200
1-27	25	25	75	1	nd	300
2-4	100	nd	300	50	100	400
2-5*	75	nd	350	<1	nd	200
3-2	75	nd	100	<1	10	300
3-3*	75	nd	350	1	10	200
4-1	50	nd	200	<1	nd	500
4-3*	50	nd	100	<1	nd	400
5-2	50	nd	75	<1	nd	200
5-5	75	nd	350	1	nd	500
6-1	75	nd	700	1	10	100
6-4	100	nd	400	<1	nd	100
7-4*	50	nd	400	10	nd	100
7-5*	50	10	800	<1	nd	400
7-6*	75	25	800	1	nd	50

* Sample containing some dolomite.

[1] First part of sample number is sample location (fig. 1); second part indicates stratigraphic position, increasing numerically upward.

[2] nd = not detected.

source area could result in the migration of great amounts of fresh bivalent manganese, which would be precipitated on contact with the higher pH of sea water. A large influx of fresh water would change the pH of sea water quite a distance from shore; consequently, manganese would be precipitated onto the seafloor sediments quite a distance from shore. In an arid climate, however, sparse vegetation, low discharge of streams, and slow weathering would result in oxidation of bivalent manganese and conversion to immobile manganese in a higher valence state (Mn^{+3}). Consequently, there would be less migration of manganese in an arid climate, and it would be precipitated near shore.

The average manganese content of the 30 Foraker samples was 240 ppm, slightly below the average obtained by Ronov and Ermishkina for carbonate rocks of an arid climate. Allowing for the limited number of samples analyzed, this figure may be considered near enough to the average for arid-climate carbonates to indicate an arid paleoclimate during Foraker deposition.

The maximum manganese concentration (800 ppm) was found in two dolomite-rich samples. It is important to determine whether the manganese is an impurity in the rock or whether it is incorporated into the calcite or dolomite structures. Solid solution in the system $CaCO_3$-$MnCO_3$ is extensive and many examples of manganoan calcites and calcian rhodochrosites are known (Goldsmith, 1959). Goldsmith (p. 340) has shown complete solid solution between 0 to 50 mole percent $MnCO_3$ at temperatures to approximately 400°C, demonstrating that manganoan calcites may be formed at moderately low temperatures.

In the binary system $MgCO_3$-$MnCO_3$, although Mg^{+2} and Mn^{+2} cations differ in radius, solid solution is extensive. $MnCO_3$ tends to take up more $MgCO_3$ than vice versa (Palache, Berman, and Frondel, 1951) because the radius of Mn^{+2} (0.92 A) is larger than that of Mg^{+2} (0.78 A), and the smaller ion substitutes for the larger more readily.

Frondel and Bauer (1955, p. 758) reported that an ordered compound of the dolomite type between magnesium and manganese would appear as likely as that between calcium and manganese, because the difference in ionic radii in the two situations in identical.

Although it was not within the scope of this study to determine the nature of occurrence of manganese in the dolomitic samples, the manganese is probably partly incorporated into the systems $MgCO_3$-$MnCO_3$ and $MnCO_3$-$CaCO_3$ and partly associated with impurities in the rock.

STRONTIUM

The strontium content of 30 carbonate samples ranged from 50 to 900 ppm. A significant correlation exists between the strontium and dolomite contents of the samples. Twelve samples (table I) contained different amounts of dolomite (determined by x-ray diffraction), and eight of the twelve dolomitized samples contained 50 to 200 ppm strontium, which is less than the average strontium content of nondolomitized samples (350 ppm). The lowest strontium content was found in sample 7-6, which is approximately 90 percent dolomite. These data indicate a loss of strontium during dolomitization, a conclusion which agrees with Stout's (1941) analysis of Ohio dolomites, showing bimodal strontium distribution. He found that low-strontium dolomites are free of celestite, but that high-strontium samples contain measurable percentages. Graf (1960) also suggested that the strontium content of dolomite may be either less or more than that of limestone, depending upon whether celestite is present. No celestite was found in the dolomitized carbonate samples of the Foraker Formation.

Most strontium introduced into carbonate sediments substitutes for calcium in the aragonite structure and to a lesser extent in calcite. The orthorhombic aragonite structure accepts the larger cations more readily than does the rhombohedral calcite structure; this tendency may be reflected in a higher strontium content for aragonite. Cork

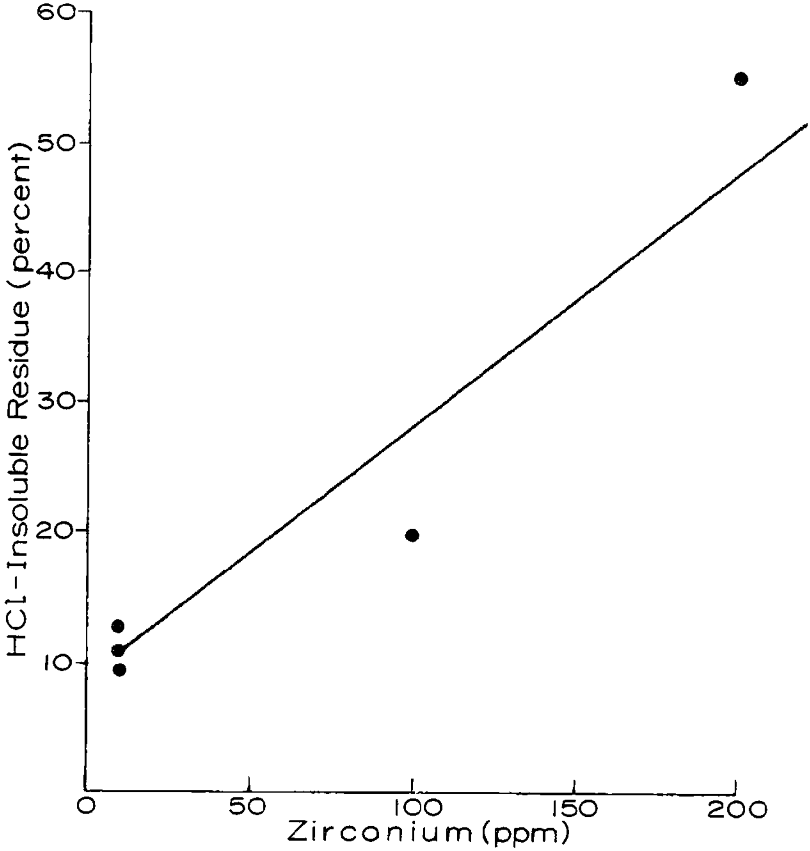


Figure 2. Relationship between insoluble-residue content and zirconium concentration.

and Gerhard (1931) demonstrated a complete solid solution of strontium into the orthorhombic structure.

On evidence from recent carbonate sediments that aragonite is precipitated in preference to calcite (Cloud, 1960, in Kahle, 1965), many investigators (Cloud and Barnes, 1957; Ross and Oana, 1961; Brown, 1959, p. 265; Campbell, 1962, p. 495; Bergenback and Terriere, 1953, p. 1022) contend that aragonite is the primary precipitate and that it is altered diagenetically to calcite or dolomite. Thus, the original carbonate sediment may have had a higher strontium content and, during alteration from aragonite to calcite, some strontium may have been liberated (Stehli and Hower, 1961; Turekian and Armstrong, 1961, p. 1818).

The average strontium content of aragonite and calcite samples shows more strontium in association with aragonitic materials (Kahle, 1965, p. 847).

ZIRCONIUM

Zirconium was detected in only five samples, ranging in concentration from 10 to 200 ppm. There is a positive relationship between the insoluble residues of carbonate rocks and their zirconium contents (fig. 2); the percentage of zirconium increases with an increase in the insoluble-residue content. The insoluble residues for these samples are similar—essentially quartz, clay minerals (montmorillonite, illite, chlorite), and minor amounts of feldspars. Adams and Weaver (1958) demonstrated a linear relationship between the zirconium and insoluble-residue contents, and Degenhardt (1957, in Graf, 1960, p. 39) suggested that the entire zirconium content of carbonate rocks may be in the insoluble residues.

The zirconium in the Foraker carbonates may be associated with clay minerals as a minor lattice component and with the heavy minerals in trace quantities.

CONCLUSIONS

The trace-element contents of the carbonate rocks of the Foraker Formation show no consistent pattern, but some elements, such as manganese and strontium, provide information on their paleoclimatic and diagenetic history. The average manganese content is near the value obtained by Ronov and Ermishkina (1959) for carbonate rocks of an arid climate. It is thus probable that the paleoclimate during the deposition of the Foraker Formation was arid.

The strontium content of the dolomitized samples was commonly lower than that of the nondolomitized samples, indicating a loss of strontium during dolomitization. No systematic relationship was found between the strontium content of the rocks and the degree of recrystallization.

The zirconium content of the Foraker Formation shows a positive correlation with the insoluble residue of the carbonate rocks. It is believed that the zirconium is in part incorporated into the lattices of the clay minerals and in part is found with the heavy minerals as a trace of zircon.

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Summaries of Symposium Papers

Austin, Texas; November 16-17, 1967

"Limitations of the Earth— A Compelling Focus for Geology" was the theme of a symposium held in connection with the dedication of the new geology building at The University of Texas at Austin (November 16-17, 1967). The talks presented dealt with problems of vital interest to all geologists, but particularly to those in mineral resource-related fields. Summaries of several of these talks appear on the following pages and are reproduced from the dedication program with the kind permission of the authors and of P. T. Flawn, director of the Texas Bureau of Economic Geology. The assistance of S. E. Clabaugh in obtaining this permission is also gratefully acknowledged.

All of the talks will be published in whole in the *Texas Quarterly,* probably in the summer or fall of 1968. In addition to those summarized here, *The Role of Geological Concepts in Man's Intellectual Development* by James Gilluly, U. S. Geological Survey; *Geological Information for Managing the Environment* by John C. Frye, Chief, Illinois Geological Survey; *Energy Resources* by Charles F. Jones, President, Humble Oil & Refining Company; *Raw Materials Unlimited* by Alvin M. Weinberg, Director, Oak Ridge National Laboratory; and *Searching Out Resource Limits* by William T. Pecora, Director, U. S. Geological Survey, will be included in that issue of the *Quarterly.*

Realities of Mineral Distribution

PRESTON E. CLOUD, JR., University of California, Los Angeles

Minerals and other raw materials are not distributed equally over the earth. Neither do they occur in a continuous spectrum of grades that makes their availability a simple function of energy input, economics, or technology—powerful though such factors are. In spite of all that can be achieved with sufficient application of power, intellect, and population control, the world and its resources are finite and thus eventually impose limits both on population and on rates of consumption. The resources of the sea may well prove to be large, but they are at present not known in detail, are almost certainly overestimated by advocates, and will require much effort and ingenuity to exploit. Extraterrestrial resources for earthly use exist only in science fiction.

The concept of unlimited mineral resources denies the restraints and belittles the difficulties. It is based on five main premises, none of which can be taken without reservation, and some of which are less supportable than others. Wide uncritical acceptance of these soothing premises contributes to a dangerous complacency toward problems that call not only for intensive, wide-ranging, and persistent scientific and engineering investigation, but also for new social patterns and wise legislation.

The realization of premise I, the promise of essentially inexhaustible cheap useful energy, involves the perfection of a workable breeder reactor within time limits that will not unduly strain reserves either of the fossil "fuels" or of naturally fissionable U^{235}. It also assumes the solution of as yet unsolved problems in the application of nuclear energy to the exploitation of low-grade sources of minerals and attributes a primacy to energy *per se* that is by no means established. In the very long range, of course, fusion must be invoked. The fossil "fuels" should be reserved for petro-chemicals, polymers, essential liquid propellants, and other special purposes not served by nuclear fuels.

Premise II, the thesis that economics is the sole factor governing availability of useful minerals and metals, can be justified only for selected items such as Fe, Al, and Cu and, for them, only on the assumption of an indefinite continuance of current trends and access to foreign deposits. Economic indexes, moreover, minimize the vitamin-like quality for the economy as a whole of the raw materials whose enhancement in value through beneficiation, fabrication, and exchange accounts for a large part of the material assets of society.

Premise III, the fallacy of uninterrupted variation from ore to average crustal abundance, which is inherent in premise II, is simply not so for many critical materials. Sharp discontinuities exist in the abundances of mercury, helium, tin, nickel, molybdenum, manganese, and the precious metals, for example. A comprehensive geochemical census, in the framework of good supporting geological field work, and advances in many aspects of theoretical and experimental geology, geophysics, and extractive metallurgy is needed to find and delimit the sources and define the grade-levels of host rock that can produce needed substances. This is also necessary for analysis of economic adjustments that would be required to assure particular rates of supply—as well as to permit relative availability of a wide range of substances of varying physical properties to be considered at early stages in the formulation of industrial and engineering requirements.

Premise IV, the crucial assumption of population control, expresses a hope that well-informed, open-minded, humanitarian people everywhere must share; for without the stabilization of world populations at some supportable level, probably not far beyond 7 billion, the rising expectations of the poor are doomed and the affluent can remain affluent only by maintaining existing shameful discrepancies. Much greater progress than is as yet visible, however, must take place over much larger parts of the world before optimism on the prospects of voluntary global population control can be justified.

Premise V, the notion of the technological fix, carries the seeds of complacency and dehumanization, as well as hope. It is an anesthetic, not a panacea. The flow of science and technology has always been fitful, and population control is a central limiting factor in what can be achieved. It will require much creative insight, hard work, public enlightenment, and good fortune to bring about the advances in discovery and analysis, recovery and fabrication, use and conservation of materials, management and recovery of wastes, and substitution and synthesis that will be needed to keep the affluent comfortable and bring the deprived to tolerable levels. It will probably also take some revision of criteria for self-esteem, achievement, and pleasure if the gap is to be narrowed and demand for raw materials kept within bounds that will permit man to enjoy a future as long as his past and under conditions that would be widely accepted as agreeable.

In some instances the technological fix, like a good anesthetic, may buy time to seek better solutions or to solve a problem permanently. But sooner or later man must come to terms with his environment and its limitations. The sooner the better. The year 2038 is only as far from the present as the invention of the airplane and the discovery of radioactivity. In the absence of control or catastrophe there could be 15 billion people on earth by then! Much that is difficult to anticipate can happen in the meanwhile, and to place faith in a profit-motivated technology and refuse to look beyond a brief "foreseeable future" is one of the choices available. Against this we must weigh the consequences of error or thoughtless inaction and the prospects of identifying alternatives for deliberate courses of action (or inaction) that will affect favorably the long range future. To do nothing is equally to make a choice.

Geologists and other environmental scientists now living face a great and growing challenge to intensify the research needed to ascertain and evaluate the facts governing availability of raw material resources, to integrate their results, to formulate better predictive models, and to inform the public. For only a cognizant public can generate the actions and exercise the restraints that will assure a tolerable life and a flexibility of options for posterity. The situation calls neither for gloomy foreboding nor facile optimism, but for unremitting effort, inspired research, and a political and social climate conducive to these things.

The realities of mineral distribution are that it is neither inconsiderable nor limitless, and that we just don't know yet in the detail required for considerable weighing of rational long range alternatives where or how the critical lithophilic elements are concentrated. Coal and other stratigraphically controlled substances we can comprehend and estimate within reasonable limits of error. Reserves, grades, locations, and recovery of most metals, on the other hand, are effected by a much larger number of variables. One of these—geography—may be shifting its favors from depleting North America to virgin Siberia.

Institutions like the one whose dedication we celebrate are central to the problem of sustaining a healthy industrial society. Only they can produce the intellectual resources that can learn the things such a society needs to know about material resources. The essential supplements are adequate support and a vision of the problem that sweeps and probes all aspects of the environmental sciences.

Population, Food and Environment: Is the Battle Lost?

PAUL R. EHRLICH, Professor of Biology, Stanford University

The facts of population growth are simple. Any population will continue to grow as long as individuals are being added to it more rapidly than individuals are being subtracted from it. In a closed population, one in which immigration and emigration do not occur, the situation can be summed up a little differently. A closed population will continue to grow as long as birth rate exceeds death rate. The human population of the earth is closed, and its birth rate exceeds its death rate. No population can become infinite. Sooner or later, then, there must be a decrease in the birth rate of the human population, or the death rate will inevitably increase. A corollary of this is that anyone or any organization opposing reduction in the birth rate is automatically an agent for eventually increasing the death rate.

The simple arithmetic of population dynamics confronts mankind with a vast array of complex biological and socio-political problems. The most pressing involves a search for a global consensus on the size of an optimum population for this planet. We must view the earth as a space ship of limited carrying capacity. If we are to design environmental systems which will sustain the human crew of the ship in an optimum state, we must first determine the size of the crew. Most difficult, of course, is the problem of defining "optimum state"—especially since opinion will vary among cultures. Nonetheless, we have no choice except to attempt to solve the problem.

What is the state of the environment now? Food production is falling behind population growth at a distressing rate. Our exposure to poisons in air, water, and food is increasing. Alteration of delicately balanced ecological systems (ecosystems) has in many areas produced deleterious and often irreversible changes. Planned technological "advances" promise a further acceleration of this process. Perhaps our "psychic environment" has deteriorated even more than we realize. Unhappily our understanding of the subtle relationships between the psychological needs of people and their environment is in its infancy. And it may not survive to adolescence, for the danger of a thermonuclear holocaust increases with increasing population pressure.

If there is to be any chance of avoiding catastrophe we must move rapidly to stabilize the population of the United States and then to turn our national attention to the problem of *reducing* the total number of *Homo sapiens* to a predetermined level. Some biologists feel that compulsory family regulation will be necessary to retard population growth. It is a dismal prospect—except when viewed as an alternative to Armageddon. I would like to suggest four less drastic steps which might do the job in the United States. I suggest them in the full knowledge that they are socially unpalatable and politically unrealistic.

First, establish a Federal Population Commission with a large budget for propaganda supporting reproductive responsibility.

Second, change our tax laws so that they discourage rather than encourage reproduction.

Third, pass Federal laws which make instruction in birth control methods mandatory in all public schools.

Fourth, change the pattern of Federal support of biomedical research so that the majority goes into the broad areas of population regulation, environmental sciences, behavioral sciences, and so forth, rather than into short-sighted programs on death control.

Once this country is on the road to population stability the full weight of our power and prestige should be placed behind an international program of population control. Until our own house is in order our motives are certain to be questioned. Having moved toward stabilizing our population we will be in a position to apply pressure on other countries to do likewise. In particular we can attach "strings" to our aid to countries with burgeoning populations. Every dollar's worth of food or other aid would have to be paid for in effort toward population control.

Above all, we must fight any trend toward symptomatic treatment of the population problem—increased food production and environmental manipulation do nothing to cure the cancer of population growth. Like many other cancers, the longer it is untreated, the greater is the chance it will become fatal.

Consequences of Man's Alteration of Natural Systems

ROBERT F. LEGGET, Director, Division of Building Research,
National Research Council, Canada

The term "solid earth" must have misled all too many non-scientists into misconceptions about the way in which the earth reacts to the stresses that are induced in it by man's activities. Geologists know better than to be so misled, their own studies of the natural forces which have led to existing geological structures vividly illustrating the fact that the materials in the crust of the earth can be stressed and strained in exactly the same way as all other solid materials.

Despite this recognition of the effect of natural forces on the grand scale in geological processes, it may be sometimes forgotten that even the activities of man—through engineering works—can have local effects on the materials that make up the crust of the earth that may be serious.

It is here that the consequences of man's activities on natural systems are most vividly to be seen. Even interference with the operation of natural processes, without inducing any additional stress in the earth's crust, can cause troubles and show quite remarkable consequences.

A small but vivid example of this from Australia, with geological overtones, will provide a good start for the case histories that will be reviewed briefly in illustrating some of the ways in which man's activities on the earth have resulted in serious consequences. The serious effects of some ancient maritime works in the Mediterranean region are well known to students of history but it is not always realized that the same sort of thing has been happening in more recent years.

The scale of such effects makes them unusually difficult to predict but already some results of the construction of the Suez Canal, for example, linking two oceans, can be measured. It is, on the other hand, yet too early to see whether the blocking off of the Strait of Canso between the mainland of Canada and Cape Breton Island is having any serious effect on the natural environment.

The works of man on land, such as excavation, or blasting, are relatively puny as compared to geological phenomena, in so far as the stressing of solid material is concerned. When, however, ground-water conditions are interfered with, this may affect such a large volume of the upper part of the crust that quite unusual forces can be set in motion with consequences that may be serious and are sometimes surprising.

On such an occasion as this, the serious land subsidence in the Houston area, due to pumping, must naturally be mentioned. Even more serious have been the effects of pumping in some areas of California, notable in the vicinity of Long Beach. In Japan there may be found even more serious consequences of interference with natural ground-water conditions. Other examples could be given from other parts of the world, all demonstrating how the extraction of fluids from the voids in the upper portion of the earth's crust can seriously affect the conditions at the ground surface.

The process can be reversed. There is a good example from one of the cities of Germany which shows how the control of ground water can assist with the control of ground subsidence, and therefore of the settling of buildings. One area in France, fertile through irrigation, was seriously interfered with when a large run-of-stream hydroelectric plant was constructed. This involved a major rehabilitation project which has proved to be quite successful.

Quite the most serious consequence of man's activities in relation to ground water that the writer has been privileged to see is the sudden increase in the development of sinkholes in the West Rand mining area near Johannesburg. The development of new mines has necessitated a great deal of deep pumping. This appears to be related, in some way, to a sudden increase in the catastrophic development of sinkholes in the surface above the mines. Lives have been lost in these suddenly formed craters which measure up to 300 feet in diameter and 200 feet deep. They have a geological interest all their own, man-made Karst topography being a disturbing thing to see.

All the cases described are serious in themselves. Their significance is the more serious when considered in relation to the current development in construction operations throughout the world. Because of the present "population explosion", and making every possible allowance for modifying factors, it seems certain that well before the end of this century the population of the world will be doubled, at least. This means that the world has got to build in the next 30 years as many structures of all sorts as exist on the surface of the earth today. The consequences of this activity provide much food for thought and confirm the eminent desirability of focusing attention on this aspect of the "limitations of the earth", together with the other phases considered in other papers.

Future Metal Supplies, The Problem of Capability

THOMAS S. LOVERING, U. S. Geological Survey

Future mineral resources depend on cost of supplying market places, and this is a function of relative locations, cost per unit of mine output, market price, and any institutional incentives or restrictions placed on operations.

Current economic doctrine assumes unrestricted access of market to all deposits, and a continuous geometric increase in reserves with lessening grade, and, as a corollary of these assumptions, unlimited supplies for a gradual rise in price. It is also assumed that improved technology will continue to lower costs per unit output into the foreseeable future or provide satisfactory substitutes at lower costs. These assumptions are supposed to hold for all minerals.

All these assumptions are debatable and may lead to a state of lethal complacency. The unrestricted access principle does not hold between many Communist and non-Communist countries, or between areas where cartels or mineral monopolies allow capricious control of major sources of supply.

The doctrine of geometric increase of tonnage with arithmetic decrease in grade (the G/A ratio) can hold for only a few ores. In general the closer ore grade approaches the clarke of the element, the better does this empirical rule apply. There is no known geologic reason why it should be true for most types of geologic processes. It best approximates relations in sedimentary ores, certain types of residual ores, and for disseminated ores. It does not hold for most veins, replacement deposits in carbonate rocks, nor even for magmatic segregations.

Iron and aluminum ores may well follow the G/A ratio rule. Many porphyry copper deposits show the G/A ratio from ore grade to marginal grade as pointed out by Laskey, but even these best examples fail both in the ranges of low submarginal ore and high grade ore. The product of grade times price gives an index which over a period of time clearly reflects the trend of technology in reducing costs per unit of output. For copper this index fell steadily till about 1950 and since then has been nearly constant. Using tonnage-grade relations and assuming a grade times price index equals a constant, one can derive an empirical tonnage-price relation to estimate reserves at various prices. This is the basis of a Bureau of Mines computerized procedure that gives figures for reserves of mercury in the U. S. Even these figures provide little comfort for the long term outlook; when U. S. mines are exploiting ore carrying 1½ lbs. per ton, the value of mercury should equal the present value of silver—$1.35 an ounce.

Of the many other metals that are essential vitamins for industrial giants, acute supply problems loom ahead if present trends in demand and supply continue, and several of these metals are discussed briefly.

The consumption of metals in the U. S. is increasing at about double the rate of population growth. Elsewhere it is generally less, and is less than the fertility rate in some underdĕveloped countries. The present rapidly increasing disparity between the per capita incomes of the U. S. and under-developed countries will persist until birth rates in such countries fall notably. Some demographers believe this will happen very soon. When it does the demand for metals will increase exponentially. Before this happens governments of industrial nations must take suitable institutional action to provide equitable access to sources of supply; it is essential that they also provide lead time and funds for appraisal and the technological development appropriate to the 21st century.

Earth's Tolerance for Wastes

P. H. McGAUHEY, Director, Sanitary Engineering Research Laboratory, University of California, Berkeley

As a prelude to a consideration of the capacity of the earth to recover from insult, some basic concepts should be recalled. First, wastes are essentially the residues of man's use of the earth's resources, not just the tailings of production but, eventually, the product itself. This is to say that any matter becomes a "waste" whenever its owner loses interest in ownership and no longer wants it in his sight—or in his garage.

Next, the indestructability of matter dictates that it must go along with the earth in its journey around the sun. "Into the air, into the water, or into the land as gases, liquids or solids" defines the entire spectrum of possibilities for handling wastes. To be sure, we have added "into orbit" and "into space" as the possible destiny of matter, but I am not imaginative enough to accept these as feasible alternatives. Should I be mistaken, the end of earth's tolerance for wastes will come when the cocoon of debris beyond the atmosphere shuts out solar radiation, initiates a new ice age, and Al Capp's "Upper Slobbovia" becomes a reality.

The earth's atmosphere and flowing water must be considered as transport systems of limited reservoir capacity which distribute wastes widely over land and ocean by what I shall call the "beer can" system of wastes disposal. The land and ocean represent lakes into which wastes ultimately migrate either by natural or man-made transport systems.

Finally, the earth is accustomed to dealing with a vast segment of wastes which derive from the life processes of living creatures, and from man's extractive industries. But not all of man's industry is extractive in nature. In fact, his most economically rewarding activities lead to synthetic materials for which no ecological system has any appetite; or to toxic refractory compounds which may likewise take ages to degrade.

Limited as it may be, the reservoir capacity of the atmosphere exceeds man's ability to tolerate pollutants in his envelope of air. Nevertheless, he is willing to explore the boundary conditions rather than pay the cost of eliminating much of the products of inefficient burning of fuels and of industrial processes. To this end we have identified levels of air pollution where adverse effects are evident; serious alteration of bodily function and chronic disease are likely; and air emergency situations foretell disasters such as the Donora, Pennsylvania incident. Typical of the concentrations of various substances which may damage man or plants severely are the following:

1. A combination of ozone, nitrogen oxide, hydrocarbons or aerosols at a concentration of more than 0.15 ppm for one hour.
2. Ozone at 2 ppm for one hour.
3. Nitrogen oxide at 5 ppm for one hour.
4. Sulfuric acid mist at 5 mg/M^3 for a few minutes.
5. Carbon monoxide at 120 ppm for one hour.

Obviously various combinations of pollutants in the atmosphere, conditions of exposure, and natures of exposed population are involved in the effects of any incident; nevertheless, values such as the foregoing might be said to define the tolerance of the earth's atmosphere.

Because man is not constantly in contact with water, the tolerance of the earth's fresh water system is less critical than that of the air. From the standpoint of aquatic life the tolerance for natural organic matter is defined in terms of oxygen to sustain life, and settleable solids which may obliterate food supply or spawning areas, and floating material which may shut out sunlight. To this end such "standards" as 5.0 mg/1 minimum dissolved oxygen; 20 mg/1 maximum suspended solids; absence or extremely low concentrations of toxic metals and exotic organics such as pesticides.

Man protects himself by standards for drinking water quality, too extensive to catalog here, which place limits on bacteria, metal ions, and compounds which produce tastes and odors. Such "standards" as man sets to protect himself and aquatic life, however, are generally intended to overcome the hazards of life associated with water rather than to define the tolerance of water itself or of creatures which live dangerously. Thus if a stream is treated as a beast of burden, its capacity to transport wastes is vastly greater than the tolerance of aquatic life, albeit not of men who may get their water supply elsewhere. On the other hand, if national objectives of "clean water," "pure water," "maintenance of habitat," etc., are taken too literally, tolerance becomes measured by sentiment and aesthetics and may well approach zero.

From a longer viewpoint, the tolerance of fresh water may be measured in terms of the concentration of dissolved solids resulting from storing water and using it in agriculture, industry, and municipal activities. Although man can learn to drink water with 3,000 mg/1 dissolved solids, 1,500 mg/1 is a good measure of tolerance. Animals may survive on 7,000-10,000 mg/1, but above 2,000 mg/1 the type of crop which may be grown is restricted. Intensive use is rapidly increasing the salts in water. For example, single domestic use adds some 300 mg/1 salts. Evaporation from reservoirs may be up to 10 feet per year, leaving behind the salts. Evaporation of plants concentrates salts at the root zone which must be leached away by irrigation in many areas, and returned to the water resource.

Therefore, if we consider that the limits of tolerance of water for wastes are to be measured by the effect of wastes on the dynamic equilibria which presently confronts living organisms, it must be concluded that the earth's tolerance for wastes in the fresh estuarine waters is quite limited. The tolerance of the ocean has, of course, long been considered as infinite. For nature's wastes, this may well be true. For man's wastes, no parameters have been set beyond the beaches and shallow shelf areas.

Considering that the atmosphere and fresh waters are at best transport systems with limited reservoir capacity, and an even more limited tolerance for wastes, and that much of our population lives inland from the oceans, the land must be the sink which accepts man's wastes.

Waste water spread on the land will infiltrate at a long-term rate of some 0.5 ft. of water per day. It may be injected underground at up to 7.5 gal/min/ft. of aquifer, or in deep strata at perhaps 0.5 gal/min/ft. of stratum penetrated. Bacteria and virus will be removed by soil, organic solids will be decomposed in the biologically active zone, but most stable compounds except phosphates move along with water to increase the solids in it. Metal ions and many industrial wastes (phenols, etc.) move with percolating water. Such ions must be considered minimal. Phenols and other industrial wastes move with water and so reduce its quality that man's tolerance becomes near zero.

Chemical and oil field brines have been injected into deep connate strata. The amount which the earth will accept is enormous in comparison to the amount produced by man. A rate of 0.5 gal/min per foot depth of stratum penetrated even at say, 1,000 psi, is a typical value. Waste water injected directly into water-bearing formations has been accomplished at rates up to a maximum of 7.5 gal/min per foot of aquifer penetrated. The tolerance of earth for such injections depends upon the volume and drainage of the ground-water basin—a job for both geologists and engineers to resolve in any specific case.

The fate of soluble constituents in soil gives a clue to what must be done with solid wastes. The estimated production of solid wastes in the U.S. today is of the order of 6–8 lbs/person per day. This consists of municipal refuse, agricultural residues, industrial wastes, animal manures, demolition debris, old automobiles and junk—with all the variety of chemical compounds, forms, shapes, sights and smells imaginable. Placed in a single compacted landfill this would cover 50 square miles to a depth of 10 feet annually. Of all this material the earth is tolerant—too tolerant in the case of plastics and glass.

Animal manures are worthy of special attention. In California alone some 20 million cubic yards of such wastes are produced at the point of impact between urban and rural areas in dairies, animal feed lots, and poultry and egg production installations. When it is considered that droppings from one cow in one day have the potential to produce 200,000 flies, along with man's intolerance of flies, it must be concluded that the earth's tolerance of this material along a human scale is quite limited.

From the viewpoint of the earth's capacity to accept solid wastes there are no particular physical limitations. A fill, however, may represent a pocket of infection on the land which in the long run will be picked up and carted off to the ocean by natural processes. To maintain it as a pocket man must give it all but eternal attention, protecting it from washouts, from infiltering water, from fire and erosion From this viewpoint we might say that the land tolerates solid wastes only as long as man looks after them, or perhaps, to the same extent it tolerates man.

Perhaps the limit of tolerance of earth for solid wastes is set by man himself. Even though the total production each year is impressive, it is a problem only because it is concentrated by man in limited space. Collected from the ends of the earth on 3–5 percent of the land, it confronts man with the prospect of long distance export (which he is unwilling to pay for), or living with his own wastes (which he is likewise unwilling to do), or recycling in his industry (which is a denial of his heritage of waste) or reduction in amount (which would be catastrophic to the national economy).

While he contemplates what combination of these alternatives he will accept, it well behooves him to inquire how great indeed is the earth's tolerance for wastes.

Contribution of S. W. Lowman to Oklahoma Geology

Carl C. Branson

Shepard Wetmore Lowman died at Troy, New York, on August 21, 1967, at age 68. Shep as a young man was one of the group of Tulsa geologists who formed the Tulsa Stratigraphic Society and unselfishly gave of their spare time in establishing a stratigraphic section in the area. Shep was president in 1929. He waded the small creeks in Rogers, Mayes, Wagoner, and Muskogee Counties searching for thin limestone marker beds, often finding them when he painfully stubbed his toes.

He was the finder and namer of the Tiawah Limestone (1932), the Spaniard Limestone (1938), the Sam Creek Limestone (in Wilson, 1935, p. 510, quoted from unpublished manuscript), the Inola Limestone (1932), the Enterprise sandstone member of the Boggy Formation (1932; a preoccupied name for Bluejacket Sandstone; type locality to be visited by A. A. P. G. April field trip led by Glenn Visher); the Red Oak Member of the Atoka Formation (1936; a name not used and not to be confused with the Red Oak pay sand of the Wilburton gas area). When my students and I were mapping in northeastern Oklahoma, R. H. Dott provided Shep's marked 30-minute maps, and we were able to find all but one of his localities.

Lowman's years in Oklahoma were 1928-1929 with Skelly Oil Company and 1929-1936 with Mid-Continent Petroleum Corporation. He was with Shell in Houston from 1936 to 1950 and was professor at Rensselaer Polytechnic Institute from 1950 until his death.

The brevity of Lowman's Oklahoma bibliography, given below, belies the magnitude of his contribution to the Pennsylvanian stratigraphy of the State.

1932 Lower and Middle Pennsylvanian stratigraphy of Oklahoma east of the Meridian and north of the Arbuckle Mountains: Tulsa Geol. Soc., Summaries and Abstracts of Technical Papers [Digest, vol. 1], unnumbered pages 36-39.

1933 Cherokee structural history in Oklahoma: Tulsa Geol. Soc., Digest [vol. 2], p. 31-34.

1936 Correlation [chart] of units of Cherokee Formation, *in* Conference on Pennsylvanian of Oklahoma, Kansas and North Texas: Sigma Gamma Epsilon, p. 7.

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Wilson, C. W., Jr., 1935, Age and correlation of Pennsylvanian surface formations, and of oil and gas sands of Muskogee County, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 19, p. 503-520.

Paracromyocrinus marquisi FROM THE SAVANNA FORMATION, OKLAHOMA

HARRELL L. STRIMPLE*

The genus *Paracromyocrinus* Strimple, 1966, was proposed with *Parulocrinus vetulus* Lane and Webster, from the Bird Spring Formation (Morrowan?) of Nevada, as the type species.

The species *Parulocrinus marquisi* Moore and Plummer, 1950 (= *Paracromyocrinus marquisi*), is based on a monotype (a crown with ten biserial arms) reportedly obtained from the banks of the Llano River above Mason, Mason County, Texas. Moore and Plummer (1940, p, 376) stated, "The stratigraphic horizon from which it came is not known, but judging by the occurrence of closely related forms in Kansas, it is probable that *P. marquisi* is a form of the Canyon Group (Missouri series) . . . ." Apparently the comparison was based on dorsal cups because they had remarked previously (p. 376), ". . . and another species that shows nearly identical characters of the arms is found in lower Pennsylvanian rocks of New Mexico, but *P. marquisi* is not very similar to any crinoid that is already described."

Specimens considered to be closely related have been collected by members of the Tulsa Rock and Mineral Society from the Sam Creek Member of the Savanna Formation (Krebs Group, Desmoinesian) north of Muskogee, Wagoner County, Oklahoma, and thus join with the undescribed form from New Mexico and the type of the genus (*P. vetulus*) from Nevada in suggesting a Middle or Lower Pennsylvanian age for *P. marquisi.* Rocks of Atokan age (Smithwick or Big Saline Formation) are known in the vicinity of Mason, Mason County, Texas, so no real obstacle is incurred in such an age determination.

Paracromyocrinus marquisi (Moore and Plummer, 1940)
Figures 1-2

Dorsal cup low, wide, mildly constricted at summit and with a broad, shallow basal concavity. Five basals are large plates that form the basal plane and the sides of the basal concavity and are recurved to participate in the lateral walls of the dorsal cup. Five radial plates are wide; proximal ends do not reach the basal plane and a subhorizontal shelf is formed to the fore of the ligamental areas. Two large anal plates are present. Anal X may be in contact with the posterior basal or may be separated from it by extension of the radianal plate into a posterior position.

The entire surface of the dorsal cup is marked by small pustules and granules.

The arms are long, of equal width for most of their length, and they bear long pinnules. Each secundibrach bears a horizontal ridge and is marked by granules. Measurements (in millimeters) of specimen OU 5241 are as follows:

Length of crown	75
Height of cup	11.6
Width of cup	27.5

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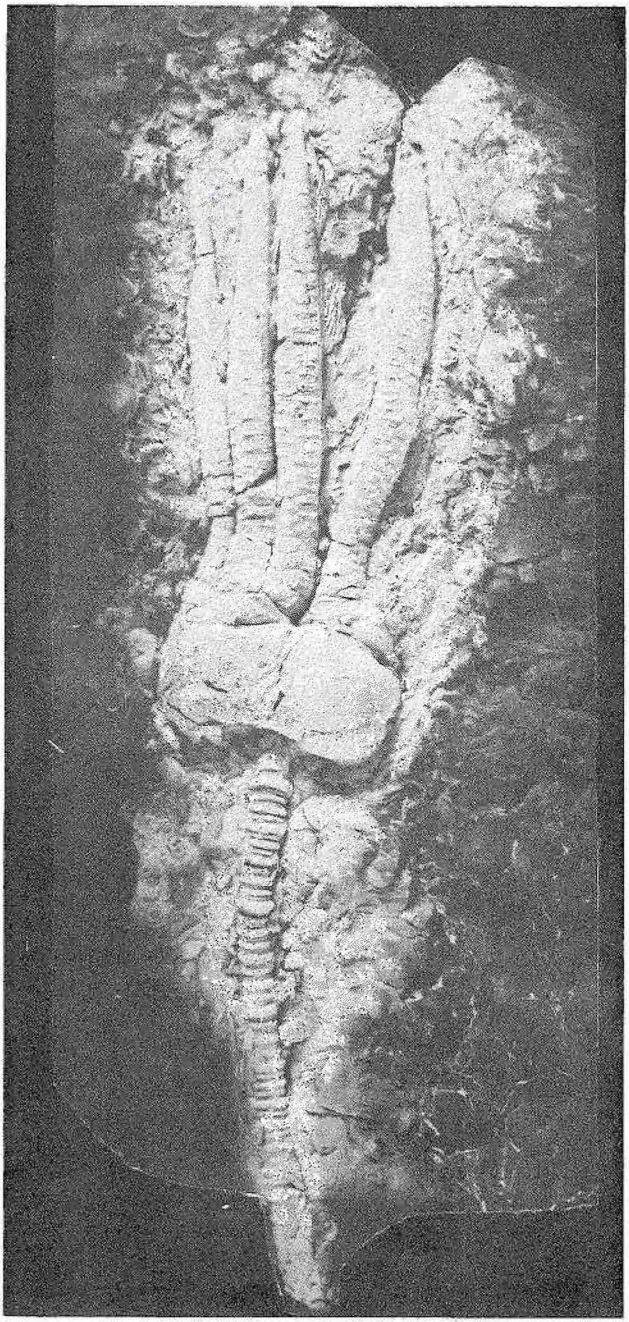

Figure 1. Paracromyocrinus marquisi **(Moore and Plummer), hypotype OU 5241, x1.2; crown viewed from posterior.**

The stem is composed of alternately expanded columnals, with five to a series. The two end ones are the largest and those adjacent are the smallest.

One specimen of *Paracromyocrinus marquisi* (OU 5665) has several arms that were broken off and regenerated about 11 mm above the summit of the dorsal cup, as illustrated by figure 2b. Evidently the new growth started near the original food groove, which is confluent with the new groove and gradually spreads toward the outer surface of the arm. It is doubtful that the full size of the original arm was ever attained.

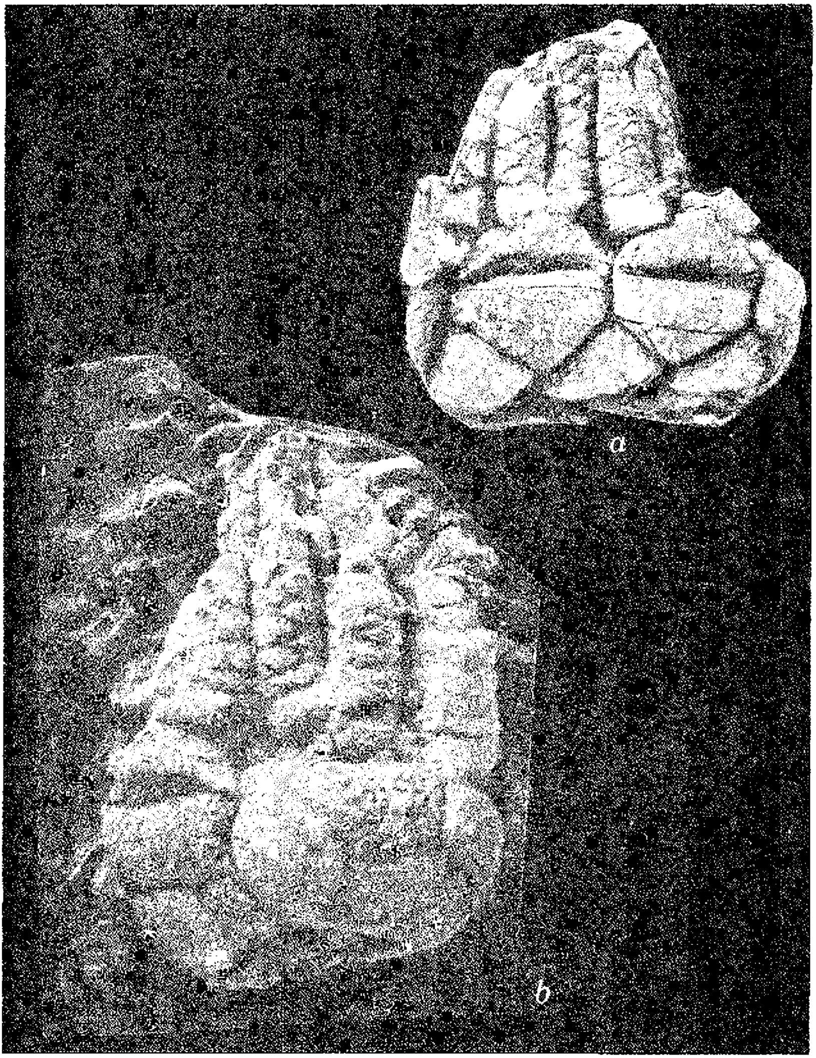

Figure 2. Paracromyocrinus marquisi **(Moore and Plummer)**

a. Hypotype OU 5664, x2.4; partial crown viewed from left posterior.

b. Hypotype OU 5665, x1.8; partial crown with regenerated arms viewed from posterior.

Remarks.—The form of the base of the dorsal cup of the holotype of *P. marquisi* is not known but is inferred to be similar to that found in the material at hand.

Typical *Aglaocrinus magnus* (Strimple) from the Pumpkin Creek Limestone is somewhat more ornate than the Savanna specimens and the arms are not known. Specimens of *A. magnus* from the younger Holdenville Formation are less ornate than the Savanna specimens and have sixteen arms. Exact affinity, if any other than general appearance, with *Paracromyocrinus marquisi* is obscure.

Material studied.—One complete crown, OU 5241, collected by E. J. Gibbon, one partial crown with regenerated arms, OU 5665, and one partial crown, OU 5664, collected by S. Grace Hower.

Occurrence.—Sam Creek Member, Savanna Formation, Krebs Group, Desmoinesian; SW¼ NW¼ NW¼ sec. 16, T. 17 N., R. 17 E, Wagoner County, Oklahoma.

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Strimple, H. L., 1961, Late Desmoinesian crinoid faunule from Oklahoma: Okla. Geol. Survey, Bull. 93, 189 p., 19 pls.

__________1966, New species of **Cromyocrinus** from Oklahoma and Arkansas: Okla. Geol. Survey, Okla. Geology Notes, vol. 26, p. 3-12, 2 pls.

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