southwest and overlap a large area underlain by shallower Green River sand lenses. Gas, apparently commercial, has been found in the Ute Trail area, which includes the Ouray, Bitter Creek, Chapita Wells, and the Southman Canyon discoveries.

Gas occurs in lenticular sands near the middle of the red, drab and gray Wasatch shale section, at depths ranging from 5,000 to 6,500 feet. Porosity averages 12% and permeability less than 1 millidarcy. Some sand bodies are continuous for four or five miles. Two or three sands 20 feet thick are generally encountered in each well.

Paleogeographic maps and cross-sections show the gas sands to lie on the north edge of a wedge of deltaic clastics brought into the basin from the south, and possibly east, and deposited in a shallow lake. This interpretation differs from published descriptions of the Wasatch as "dominantly fluviatile." Orientation of sand lenses, sorting of sand grains, and relatively great lateral extent of the sand bodies supports this concept.

Trapping is by isolation of the sand bodies and by permeability barriers between lenses of porosity within a sand zone. The trend is limited on the south by a coalescence and thickening of sand bodies, which eliminates the barriers and permits the escape of gas. Hydrodynamic traps may be present here as well. The north edge is limited by poorer sorting of the sand depsoited in deeper water. Shales of the deeper water are generally dolomitic, black, bituminous and somewhat fossiliferous, and dark gray-green or drab with subordinate purplish "relict" red colors.

Richard L. Jodry and Donald E. Campau, Sun Oil Company, Billings, Montana

Small Pseudochitinous and Resinous Microfossils: New Tools for Subsurface Geologist

The study of palynomorphs (small, nearly indestructible fossils) is generally included in the field of palynology, along with the study of polospores. Palynomorphs and polospores are included in a group of fossils sometimes designated as micro-microfossils because of their small size. Work in the Williston Basin and other areas containing Paleozoic carbonate rocks indicate that certain groups of palynomorphs make an ideal tool for use by the subsurface geologist. These fossils, chiefly the Chitinozoa (possibly an extinct order of marine protozoans) and Tasmanites (probably a family of fossil algae), may be concentrated in and recovered from the insoluble residue from drill chips utilized in the course of normal sample examination. They are well adapted for use as an aid in solving problems of correlation, zonation, and age-dating. In the Williston Basin the Chitinozoa and Tasmanites have been used as an aid in the reconstruction of the Ordovician surface section, in the subdivision of this section, and in carrying these subdivisions into the subsurface. These micro-microfossils have aided in the solution of structural problems, and offer possibilities as a tool for age-dating of Paleozoic rocks over very wide areas.

Paul Kents, Saskatchewan Department of Mineral Resources, Regina, Saskatchewan

Three Forks and Bakken Stratigraphy in West Central Saskatchewan

The Three Forks and Bakken sequence in west-central Saskatchewan was laid down during a relatively brief period of mild uplift in late Devonian and early Mississippian time, preceding the beginning of the main stage in the development of the Williston Basin. This sequence, though only about 300 feet in thickness, contains a wide variety of different rock types: dolomites, anhydritic dolomites, red beds, green shales, black radioactive shales, sandstones, and clastic biostromal limestone, which make it easily recognized in well cuttings and readily correlated from well to well.

In the northwestern part of the area the pre-Mesozoic strata were folded in post-Mississippian times, truncated and then buried by Mesozoic sediments. Data assembled from nearly all exploratory wells in the area have revealed the presence of six anticlinal structures, two of which appear to be closed and of substantial length. These structures lie in a region adjacent to producing oil fields, and therefore offer good exploration possibilities. There are indications that more hidden structures may exist in which the pre-Mesozoic strata have been folded, thus adding to further oil and gas possibilities in the area.

Daniel Lum, South Dakota Geological Survey, Vermillion, South Dakota

Gravity Measurements East of Black Hills and along a Line from Rapid City to Sioux Falls, South Dakota

Gravity measurements were carried out in South Dakota during the summer of 1959 by the State Geological Survey, as part of a regional gravity study which is being supported by a National Science Foundation grant. A simple Bouguer gravity anomaly map was compiled from data of more than 500 stations in an area of approximately 2,600 square miles. A gravity traverse was established from the Black Hills eastward onto the Sioux uplift.

The configuration of the basement surface and the variations of intra-basement lithology, as suggested by the gravity measurements and some magnetic studies, are discussed. Interpretations of the gravity data are preliminary at this time.

Further gravity studies in South Dakota are planned.

Robert P. McNeal and Floyd H. Miller, Petroleum Research Corporation, Denver, Colorado

Gas in Gallup and "Tocito" Formations in San Juan Basin, New Mexico

Commercial quantities of gas can be produced from the Gallup and "Tocito" sandstones in nine fields on the southwest and west flanks of the San Juan basin. These fields are Bisti, Gallegos, Escrito, Otero, Doswell, Chimney Rock, Horseshoe Canyon, Verde-Gallup, and an unnamed field. The last four fields have only one to four wells with commercial quantities of gas. Most of the gas is produced with oil. Little gas was collected from the Gallup and "Tocito" prior to 1958. Some gas is being reinjected for secondary recovery purposes.

The Gallup sandstone is the basal member of the Mesaverde group. The "Tocito" sandstone is any sandstone lens below the Gallup formation and above the Sanastee calcareous shale and limestone. All accumulations are in stratigraphic traps which have increased trapping capacity because of favorable hydrodynamic environments with downdip water flow. Bisti field is used as an example of the trapping capacity of a stratigraphic trap. The sandstone decreases in permeability updip but does not pinch out. Under hydrostatic conditions the capillary pressure of the column of oil and gas present at Bisti would be sufficient to cause much of the oil and gas to migrate updip out of the permeability lenses. However, with favorable hydrodynamics, the oil and gas column of over 360 feet is retained.

R. E. Megill, Humble Oil and Refining Company, Carter Division, Tulsa, Oklahoma

Cost of Finding Oil in Rocky Mountains

It is possible to calculate the cost of finding crude oil in the Rocky Mountain area by means of an exhaustive examination of published data. Expenditures can be computed by applying unit costs to physical factors, most of which are readily available. The total expenditures when compared with the barrels found furnish an estimate of the cost per barrel. The cost of finding per barrel for three areas covering much of the interior United States is as follows.

	Cost of Finding Per Net Barrel	
Area	1942–1957	1953–1957
Rocky Mountains	0.41	0.86
Kansas-Oklahoma	0.57	1.04
Illinois-Michigan Basins	0.70	1.26

Costs of finding oil are increasing in most areas of the United States at a faster rate than development and producing costs; they are expected to increase in the future. To find more oil at less cost is the challenge to the petroleum geologist.

D. N. Miller, Jr., Lion Oil Division of Monsanto Chemical Company, Casper, Wyoming
Uses of Petrographic Microscope in Petroleum Exploration

The petrographic microscope provides a direct visual means of observing and measuring the chemical and physical properties of sedimentary rocks. Through its use the geologist is able to study the details and relationships of a sediment that have a direct bearing on the majority of our exploration problems. In the past five years numerous exploration offices in the Rocky Mountains have acquired petrographic microscopes for use on routine problems. Petrographic information is being used effectively now to supplement other types of geological and engineering data in the following ways: (a) to assist in the interpretation of depositional environments, textural trends and facies patterns by revealing the primary character of the rock, i.e., composition, texture and fabric; (b) by showing the secondary changes that the rock has undergone since deposition such as mineral alteration, the development of solution cavities, fracturing and cementation; (c) by providing a visual method of analyzing porosity and its relationship to both the primary character and the secondary changes; (d) by revealing the age relationship between cementation, fracturing and porosity development with respect to the times of fluid movement and to the time of oil accumulation, and (*e*) by providing detailed mineralogic data that can be applied statistically toward the identification and correlation of specific sedimentary bodies.

Variations on standard techniques are being employed to adapt petrographic data to all types of geological and engineering problems. In the future, exploration offices will depend more heavily on petrographic information in helping to define comparable and noncomparable data associated with exploration leads. From this usage will evolve new geological concepts that will materially increase our knowledge of sedimentary rocks, porosity and permeability, fluid migration and oil accumulation.

Maurice H. Smith, Northwest Geological Service, Bismarck, North Dakota
Revised Nomenclature for Williston Basin

A revision of the 1954 publication of the "Stratigraphy of the Williston Basin" is nearing completion and will be published early in 1960. The revision is by six stratigraphic committees of the North Dakota Geological Society. The six committees also coordinate their nomenclature selections with the North Dakota Geological Survey. The Saskatchewan Canadian Government and the Saskatchewan Geological Society have given their approval to the nomenclature revision of the Mississippian group.

The committees have divided their work as follows: 1—Cambrian-Ordovician-Silurian; 2—Devonian; 3—Mississippian Madison group; 4—Mississippian Big Snowy group-Pennsylvanian; 5—Permian-Triassic-Jurassic; 6—Cretaceous-Tertiary. Close coordination among the committees is being carried on at all times. In addition to the preparation of regional cross sections, each committee is preparing branch cross sections to the regional cross sections, maps, nomenclature charts and electric survey type-section logs pertinent to its particular problem.

Although some nomenclature revisions may be made before publication, the following are group and formation divisions by four of the committees.

I. The Cambrian-Ordovician-Silurian have been divided as follows. The Cambrian has been classified as the Cambrian-Deadwood formation. The Ordovician has been divided into the Winnipeg, Red River, Stony Mountain, and Stonewall formations. The Winnipeg formation contains a lower, middle and upper member. The Stony Mountain formation has been subdivided into Stoughton and Gunton members. The Silurian has been classified as the Interlake formation. In the latter formation, two electric survey markers have been selected and named the Tioga and the Croff.

II. The Devonian sediments have been divided into the Elk Point, the Manitoba, and the Jefferson groups overlain by the Three Forks formation. The Elk Point group has been subdivided into the Ashern, Winnipegosis, and Prairie formations. The Winnipegosis formation contains a lower and upper member. The Manitoba group has been subdivided into the Dawson Bay and Souris River formations. The Jefferson group has been subdivided into the Duperow and Bird Bear formations.

III. Overlying the Devonian is the Mississippian Bakken formation. Above the latter sediments is the Mississippian Madison group. Previous designation of the Madison group consists of the Lodgepole, Mission Canyon, and Charles formations. These formations have now been classified into the Lodgepole, Mission Canyon and Charles facies in the light of more intimate knowledge of the stratigraphy. In addition, five marker-determined intervals and two sub-intervals are defined wherever they are recognizable for correlation purposes. The Madison group facies are commonly crossed by several of the intervals which are defined by log deflections. A marker-determined interval may, and frequently does, occur in more than one facies. The three facies are not generally traceable throughout the Williston Basin, but are identified and present in the correlation chart. For each of the six selected areas in the Williston Basin, a type log is presented. Each of the six type logs indicate porosity sections which are identified with the name or names they have come to be known by in the past. The Mississippian Madison group committee wishes to emphasize that the criteria for identification of the above mentioned intervals are based on log deflections or "markers," not on lithology.

IV. The Mississippian Big Snowy group-Pennsylvanian have been divided as follows. The Big Snowy group has been subdivided into the Kibbey, Otter, and Heath formations. The Kibbey formation contains a lower, middle and upper member. The Pennsylvanian