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.

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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.

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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 sediments comprise the Tyler and Minnelusa-Amsden formations.

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Pennsylvanian Gas in Four Corners Region

Pennsylvanian accumulations of gas and casing-head gas in the Four Corners region (junction of Utah, Colorado, New Mexico, and Arizona) occur in carbonates of Desmoinesian age (Middle Pennsylvanian) in four lithologic zones of the Paradox member of the Hermosa formation. These zones, from oldest to youngest, have been named Barker Creek, Akah, Desert Creek, and Ismay. They are shelf counterparts of basinal evaporitic sequences.

Reservoir beds are calcirudite, calcarenite, and sparsely to moderately fossiliferous carbonate, which is nearly in place and was deposited in biostromal and biohermal complexes. Dolomitization and other diagenetic changes have affected these units. Vuggy and intercrystalline porosity are predominant; fracturing is important in some places.

Only in a few instances can the type of trap, with fair assurance, be defined from present subsurface control. Structurally, all of the gas fields are found on surface or subsurface highs of varying relief and areal extent. Sedimentary compaction has contributed to this relief in some places, and late Pennsylvanian-Permian warping has occurred. Most of the present structural relief of these structures is due to folding during the Laramide orogeny. Stratigraphic variations, from porous reservoir beds to nonporous units, are a contributing factor in most accumulations, and the major controlling factor in some.

Eleven gas and five casing-head gas fields have been found to date, but these are still largely undeveloped. The cumulative gas production to July 1, 1959, in the Aneth Complex was 9,682,004 MCF. To September 1, 1959, the cumulative production from four zones was 179,825,593 MCF at the Barker Creek field which represents slightly over one-half of the calculated original recoverable reserves of 315 billion cubic feet. Gas from the Barker Creek field, and from the Aneth Complex, is transmitted to Kirtland, New Mexico, and from there to Topock, Arizona. Buyers at Topock distribute to customers in California and southern Nevada.

These Pennsylvanian gas accumulations are believed to be essentially *in situ* occurrences. Migration was predominantly local, not exceeding a few miles; and entrapment occurred in laterally adjacent areas of bioclastics and sparsely to moderately fossiliferous carbonates. After initial entrapment, some later re-migration is believed to have occurred.

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Bar-X, San Arroyo, Westwater Creek Gas Fields, Colorado

The Bar-X, San Arroyo, and Westwater Creek natural gas fields are located on anticlinal structures having the same names, in townships: T. 16 & 17 S., R. 24, 25 & 26 E., Grand County, Colorado. The first gas in the region was discovered on the Bar-X anticline in 1948 by Stanolind Oil and Gas Company. However, further drilling was not accomplished until 1954. Development of the fields has been slow due to the lack of a market for the gas, inadequacy of the present pipeline gathering system, and to controversial estimates of the natural gas reserves.

To date, 35 wells have been drilled on the three structures with 28 of the wells completed as gas producers from one or more sands in the Dakota, Cedar Mountain, Morrison and Entrada formations. The initial production of the gas wells in the three fields has ranged from 250 MCF to over 20,000 MCF of gas per day. The B.T.U. of the gas varies from 550 to 1,150 with the lower values being confined to the gas from the Entrada formation.

The subject area is located in and near the Book Cliffs which bound the southern end of the Uinta Basin. Much of the area is extremely rugged, being dissected by deeply incised canyons and prominent cliffs. Development is largely confined to the canyons in the Book Cliffs and to the rolling terrain at their base.

The pay zones in the Dakota, Cedar Mountain and Morrison formations are largely discontinuous sandstone lenses. The lithology of these formations is extremely erratic and virtually no two adjacent wells are completed in the same sandstone bed. The Dakota sands in the San Arroyo field are the most continuous. The natural gas found in the Dakota, Cedar Mountain, and Morrison formations is primarily accumulated in stratigraphic traps. Structural control may be secondary. The over-all general region might be considered as a potential reservoir with the sandstone lenses providing concentrated accumulations within the larger reservoir. Perhaps artificial stimulation at the proper interval might result in obtaining commercial gas production, even though a porous sandstone lens was not penetrated by the well bore. A lower salt water contact has not been established in the area for these formations. Natural gas production has been obtained in the Dakota formation all the way from 3,000 feet above sea level down to sea level. An upper water contact at an elevation of 3,200 feet has been fairly well established. This may infer that some peculiarities due to pressure variations caused by hydrodynamic and saline anomalies are present.

The gas in the Entrada formation is probably controlled by structure since the Entrada sand is a fairly continuous body.

Faulting in the region apparently has not affected the migration and accumulation of the gas, but has quite definitely affected the porosity of the sands adjacent to the faults.

The natural gas reserves estimated in the three fields vary considerably. Based on volumetric calculations using the porosity, pressure, sand thickness, and similar data, estimated reserves of natural gas in place vary from 2.5 billion to 8 billion cubic feet per section from the Dakota, Cedar Mountain, and (or) Morrison formations. The reserves, based on volumetric calculations, in the Entrada vary from 8 to 15 billion cubic feet per section.

The Bar-X field is the only field in the group which has a production history, having produced for approximately three years. Pressure-decline curves on the wells in this field for the Dakota and Morrison formations indicate minimum reserves of 1.5 to 5 billion cubic feet per section.

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Thickness and Distribution of Devonian Formations in Relation to Buried Pre-Madison Structural Features in Williston Basin

Rocks of Devonian age underlie all but the south-central part of a 200,000 square mile area that includes