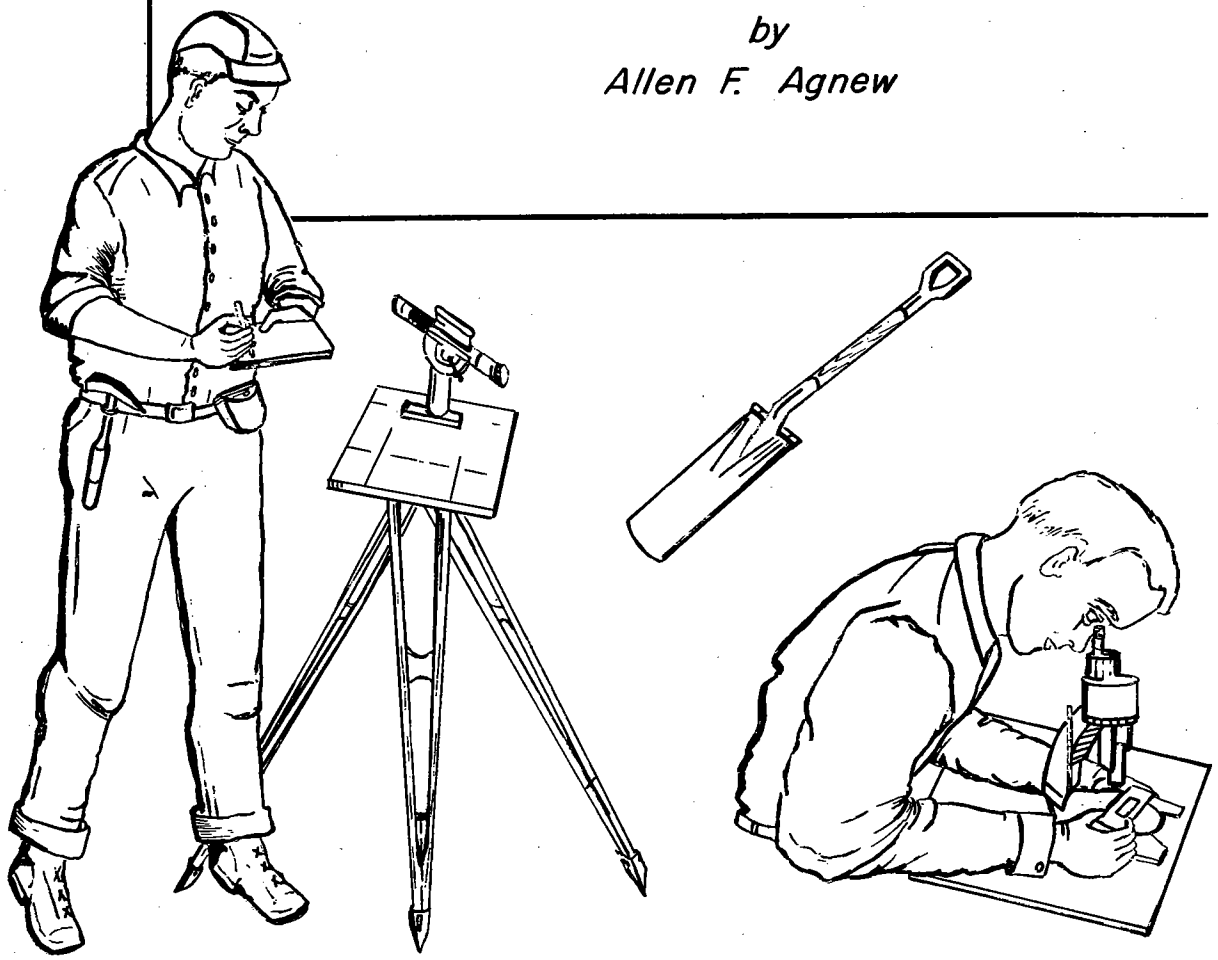
STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

MISCELLANEOUS INVESTIGATIONS NO.2

POSSIBLE UNDERGROUND STORAGE OF NATURAL GAS IN SOUTH DAKOTA

by
Allen F. Agnew



Union Building, University of South Dakota
Vermillion, South Dakota March, 1961

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UNION BUILDING
UNIVERSITY OF SOUTH DAKOTA
VERMILLION, SOUTH DAKOTA
MARCH, 1961

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POSSIBLE UNDERGROUND STORAGE OF NATURAL GAS IN SOUTH DAKOTA

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INTRODUCTION

In May, 1960, the natural-gas industry had 192 underground storage projects, with 25 new ones in the testing or planning stages (Bizal, 1960). South Dakota is not included among the 22 States where these projects are located.

Most of the storage is in depleted gas and/ or oil pools, with the remainder in aquifers (water-bearing formations). Storing gas in depleted oil pools seems to have better economic potentialities than storing it in depleted gas pools, because of the possibility of secondary recovery of liquid hydrocarbons, thus recovering part if not all of the expense of the storage operation.

Major considerations for a depleted oil or gas pool to be used for underground storage of natural gas are listed by McNutt and Chappelle (1960), as follows:

1) Geographic location of the depleted pool
2) Availability of the depleted pool
3) Number of wells in the depleted pool
4) Initial capacities of the wells
5) Cost of acquiring the necessary leases
6) Cost of reworking the wells to prepare the pool for storage

Underground storage of natural gas in aquifers is practiced in several States, including the neighboring one, Iowa.

Potentialities of storage of gas under geologic conditions suitable for LPG (liquid petroleum gas) storage, such as in salt cavities and cavities mined in granite, should be investigated.

GAS PRODUCTION IN SOUTH DAKOTA

Buffalo Field

The Buffalo oil field, in Harding County (fig. 1), has produced 56,720 MCF (thousand cu ft) of gas since it was discovered in May, 1954, until December 31, 1960. The oil pool is in the Ordovician Red River dolomite at a depth of 8500 feet; the producing zone is 12-20 feet thick. The gas-oil ratio is low, generally less than 100 MCF per bbl, and the water-oil ratio ranges from 1:5 to 20:1. Reservoir pressure is variable; initial reservoir pressure was as high as 3575 psi (pounds per sq in) in one well, but it had declined in this well to about 3050 psi in November, 1960. The oil lies along minor folds on the northeast-dipping limb of the Cedar Creek anticline, near its southern end. Porosity and permeability are variable, and the hydrodynamics of the pool are not adequately known as yet. The productive zone is overlain by 40-60 feet, and underlain by 300 feet of dolomite of the same formation. On December 31, 1960, nineteen wells were producing (fig. 2).

The Buffalo Field is 125 miles north of Rapid City, which is the nearest major consuming area; Rapid City has a population of 42,400 (1960).

Barker Dome Field

The Barker Dome Field is in Custer County (fig. 1), and has produced only a small amount of oil in its five-year life. The oil has been pumped sporadically from only one well, although several others throughout the past 30 years are said to have produced small amounts of oil for short periods. Gas is present with the oil in one well, which has never been completed as a producer.

The oil pool is in one of the "Leo" sands of the Pennsylvanian Minnelusa Formation, at a depth of 1400 feet. The producing zone is about 2 feet thick, and is in a series of dolomite, anhydrite, red shale, and sandstone. The accumulation is related to a small structural dome. Information on porosity, permeability, and reservoir pressure is not available.

The Barker Dome Field is 50 miles southwest of Rapid City, but a longer pipeline would probably be needed in order to skirt the rugged topography of the central part of the Black Hills.

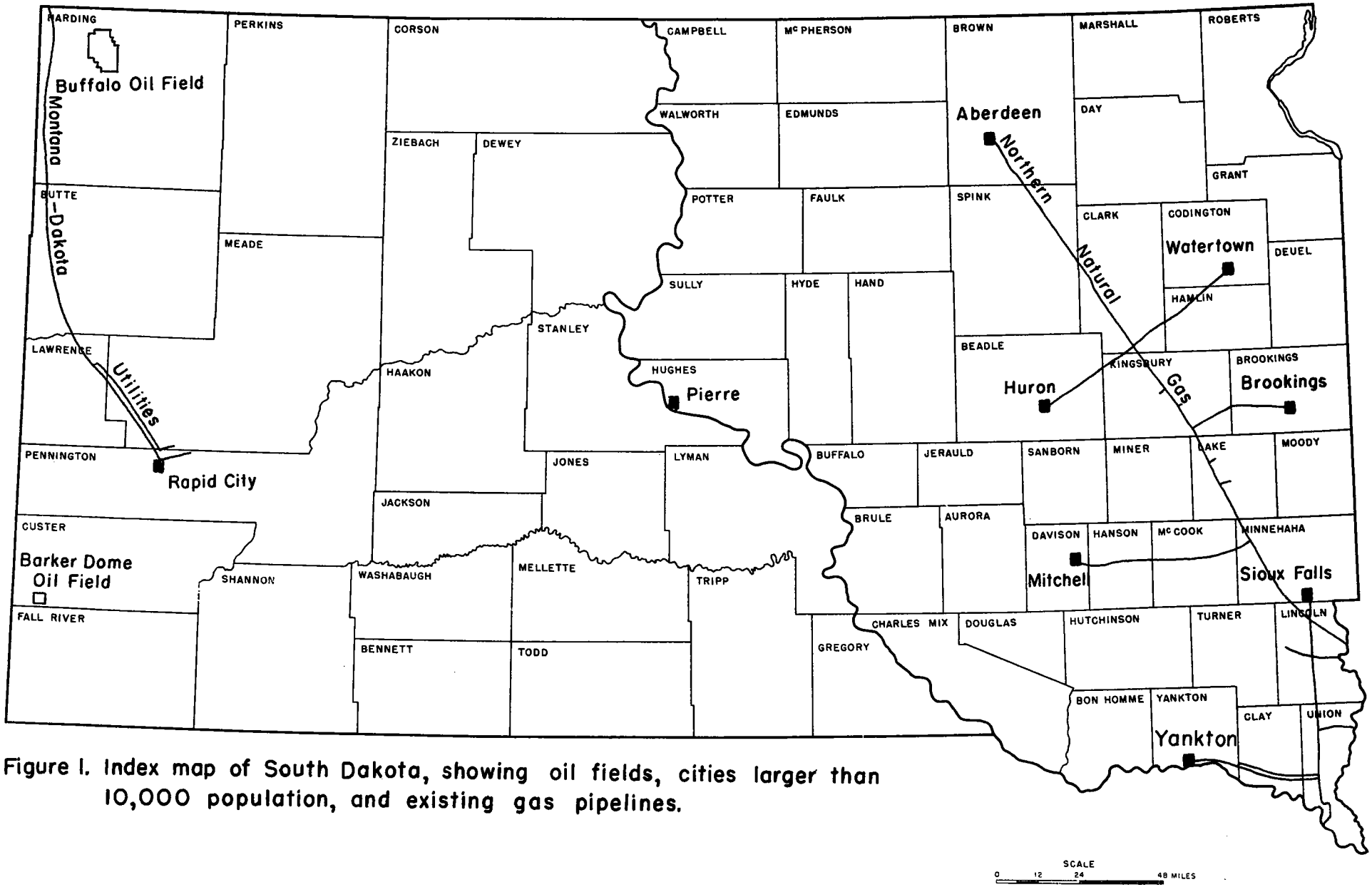

Figure I. Index map of South Dakota, showing oil fields, cities larger than 10,000 population, and existing gas pipelines.

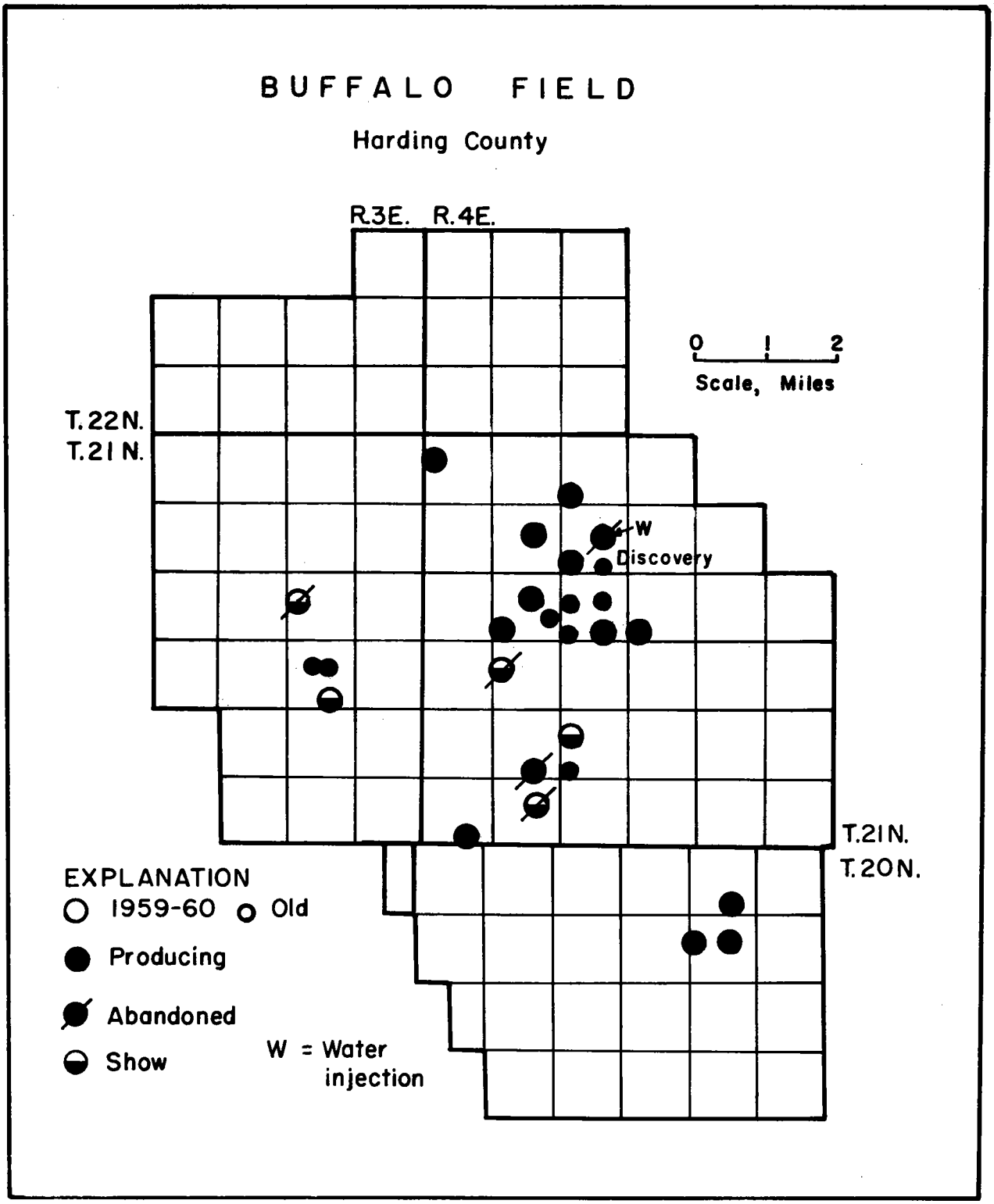

Figure 2. Map of Buffalo Oil Field, Harding County.

GAS PIPELINES AND POPULATION CENTERS IN SOUTH DAKOTA

Gas pipelines serve the eastern side of the State as far north as Aberdeen (fig. 3), and the western fringe as far south as Rapid City, thus reaching the major population centers in South Dakota.

The eastern line, owned by the Northern Natural Gas Company, obtains its product from Mid-Continent fields. The western, owned by Montana-Dakota Utilities, is fed by production in the Baker area of eastern Montana.

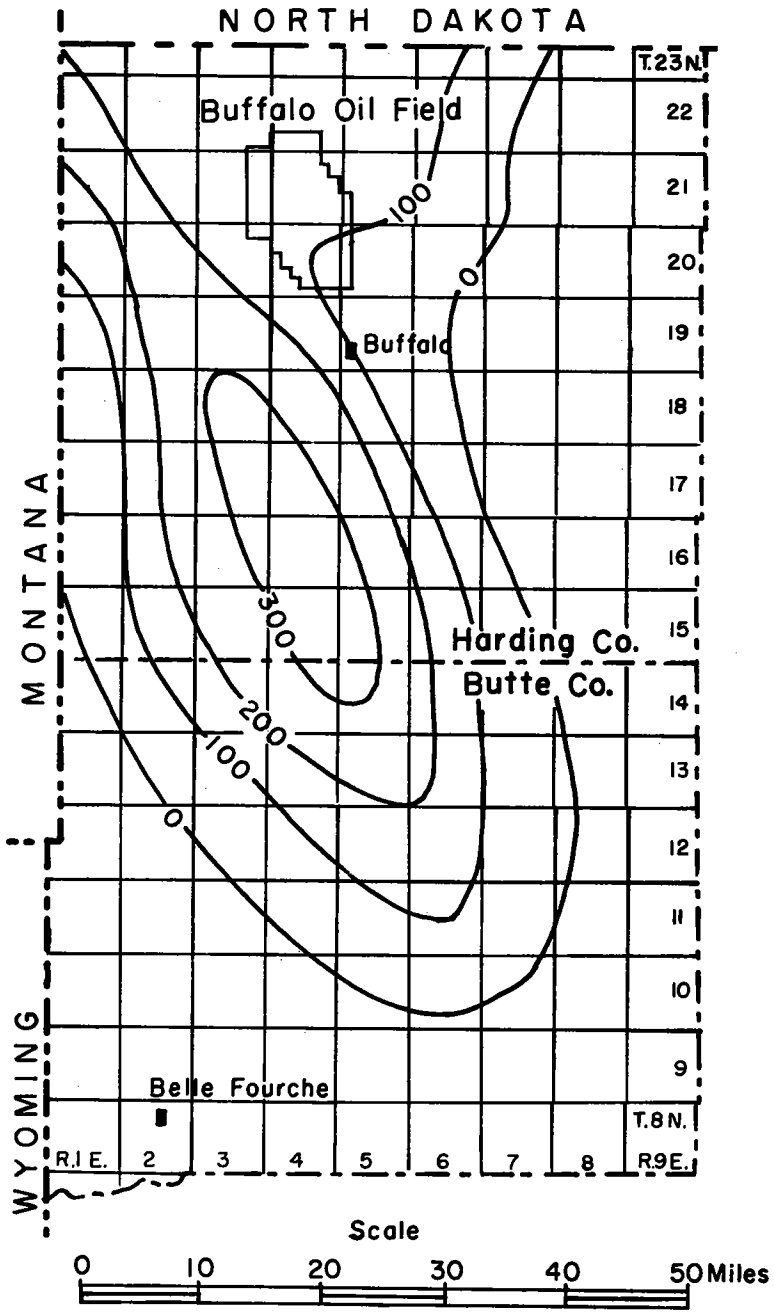

Figure 3. Map of Harding and Butte Counties, Showing distribution of Pine Salt. (Zieglar, 1956)

STRATIGRAPHY AND STRUCTURAL GEOLOGY OF SOUTH DAKOTA, WITH REFERENCE TO UNDERGROUND GAS STORAGE

The stratigraphic column for South Dakota, and information pertinent to underground gas storage, are shown in Table 1.

The stratigraphic units that possibly could serve as underground gas storage reservoirs in the western part of the State include in descending order parts of the Cretaceous Pierre shale, the "Newcastle" sandstone, the Fall River-Lakota sandstones, the Jurassic (?) Pine Salt (in Harding County), the Permian Converse sandstones, and the Ordovician Winnipeg sandstone.

In the southeastern part of South Dakota, possible underground gas storage reservoirs include the Cretaceous Niobrara chalk and Codell sandstone, the "Dakota" sandstone sequence, and the Ordovician "Simpson" or "St. Peter" sandstone (in Union County).

In the northeastern part of the State, possible reservoirs for underground gas storage include the "Dakota" sandstone sequence.

The possibility of gas storage in mined cavities in the Precambrian Sioux Quartzite or older granite in eastern South Dakota is difficult to evaluate, because of the presence of fractures and because of the lack of detailed information.

Permeability traps should be expected in the eastern half of South Dakota, where the various rock units were deposited from shoaling seas against the Continental Shield. In addition, overlaps and other unconformable situations have given rise to conditions that favor entrapment of fluids in this part of the State.

Permeability traps caused by facies changes are known in the "Newcastle" and Fall River-Lakota sandstones in the Black Hills area, and in the Converse sandstones in the northern part of that area.

The general structural elements of South Dakota include the Black Hills uplift, the Sioux Arch, and the Williston Basin (Agnew, Gries, 1960).

Small anticlines and domes are present in the rocks immediately surrounding the Black Hills, and along the Cedar Creek anticline in the northwestern corner of the State (in Harding County). It is expected that similar structures will be found in the rest of the western half of the State.

POSSIBLE AREAS FOR UNDERGROUND GAS STORAGE IN SOUTH DAKOTA

In many parts of South Dakota it appears that geologic conditions are favorable for storage of natural gas in porous rocks, as mentioned in the preceding section. In particular, around the Black Hills the "Newcastle", the Fall River-Lakota, and the Converse sandstones might profitably be prospected for small anticlinal traps.

In Harding and Butte Counties the possibility of dissolved cavities in the Pine Salt should be investigated. This salt is relatively localized (fig. 3), and reaches a maximum thickness of 300 feet (Ziegler, 1956). Storage of LPG in a similar salt zone but 3000 feet deeper, has been under way for six months in the deeper part of the Williston Basin, in North Dakota.

In northeastern South Dakota, mined cavities might be developed economically in granite.

In the southeastern part of the State, the possibility of permeability or unconformity traps in the Niobrara chalk and "Codell" sandstone might hear investigating, both where they are overlain by shale and by glacial drift.

REGULATIONS AFFECTING UNDERGROUND GAS STORAGE

South Dakota currently has no law or regulations pertaining to the storage of hydrocarbons underground. This material is included, however, in the revision of the Oil and Gas Law proposed by the State Legislative Research Council.

In other States, regulations governing the underground storage of natural gas or LPG are administered by the agency that regulates the oil and gas producing industry. Thus it is recommended that the State of South Dakota promulgate regulations to control the underground storage of liquid and/ or gaseous hydrocarbons, and that the State Oil and Gas Board administer these regulations.

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Table 1.--Generalized Stratigraphy of South Dakota with Reference to Underground Gas Storage

System	Smaller Stratigraphic Divisions	General Stratigraphic Information	Remarks Pertaining to Gas Storage
Quaternary	Pleistocene and Recent	Unconsolidated surface or near-surface continental deposits of clay, silt, sand, and gravel in valley fills and terraces in all parts of the State; mixed glacial drift east of the Missouri River; thickness as much as 750 feet.	Important fresh-water aquifers abundant; unsuitable for gas storage because of probable lack of impervious seal.
Tertiary	Pliocene, Miocene, Oligocene	Ogallala, "Arikaree", and White River--unconsolidated to semi-consolidated continental deposits of mainly silt and fine sand with some clay, gravel and ash; widespread along the south-central border; thickness as much as 900 feet.	Important fresh-water aquifers; unsuitable for gas storage because of probable lack of impervious seal.
	Paleocene	Tongue River, Cannonball, Ludlow--unconsolidated to consolidated deposits of mainly silt and fine sand with some clay and lignite, and local cemented sandstone lenses; locally in northwestern part of State; thickness as much as 650 feet.	Poor source of fresh water; unsuitable for gas storage because of probable lack of impervious seal.
		Hell Creek--like Paleocene beds above; thickness as much as 600 feet.	Unsuitable for gas storage.
		Fox Hills--marine sand, silty clay, and sandstone; in northwestern third of State; thickness as much as 340 feet.	Fresh-water source; unsuitable for gas storage because of probable lack of impervious seal.

Table 1.--Generalized Stratigraphy of South Dakota with Reference to Underground Gas Storage--Continued

System	Smaller Stratigraphic Divisions	General Stratigraphic Information	Remarks Pertaining to Gas Storage
Cretaceous	Upper Cretaceous	Pierre--marine partly bentonitic and silty shale in most of State, 1000-1200 feet thick. At base, Gammon sandy shale and Groat sandstone around northern part of Black Hills and to north, as much as 800 feet thick (Robinson, Mapel, and Cobban, 1959).	Possibility of mined cavities in shale small because of great engineering problems. Eagle sand is gas-producing along domes in Harding County, and might be investigated for gas storage there.
		Niobrara--marine chalk, marl, and calcareous shale in all but northwestern part of State; and along the Sioux Ridge in southeastern part; thickness 150-200 feet.	Local fresh-water source in southeastern part of State south of Sioux Ridge. Possibilities for gas storage locally, where overlain by impervious seal.
		Carlile--marine shale; local sandstone (Turner? or Codell?), 200-250 feet thick in southern part of State; thickness about 550 feet.	Sand is fresh-water source, perhaps connected with overlying Niobrara. Possibilities for gas storage locally.
		Greenhorn--marine limestone and calcareous shale. Belle Fourche--marine shale and bentonite. Mowry--marine siliceous shale and sandstone lenses. Total thickness as much as 900 feet.	Thin lenticular sands in southern Black Hills (Wall Creek?) are poor gas sources. Unfavorable for gas storage.
	? Cretaceous	"Newcastle"--lenticular marine sandstone in several benches, each as much as 40 feet thick; in central part of State combines with underlying Fall River into a deltaic sand as much as 400 feet thick.	Local source of fresh water and gas around Black Hills. Source of brackish water and gas in central part of State. Possibilities for gas storage in central area.

Table 1.--Generalized Stratigraphy of South Dakota with Reference to Underground Gas Storage--Continued

System	Smaller Stratigraphic Divisions	General Stratigraphic Information	Remarks Pertaining to Gas Storage
	Lower	Skull Creek--marine shale; thickness 250 feet; absent in eastern half of State.	Unfavorable for gas storage.
		Fall River-Lakota--marine and continental sandstone, siltstone, shale, and lignite (Waage, 1959); thickness 300-335 feet.	Source of fresh and brackish water throughout State. Possibilities for gas storage.
Jurassic		Morrison-Sundance--marine and continental shale and sandstone; thickness as much as 400 feet. "Sundance" in north-central and northeastern parts of State is perhaps Lakota and Sundance sands, combined.	Locally fresh and brackish water. Generally unfavorable for gas storage because of lenticularity. "Sundance" of northeastern part of State good source of fresh to brackish water, under considerable artesian pressure.
		Gypsum Springs--local marine sandstone as much as 50 feet thick in Black Hills area; changes toward the north into Piper limestone and calcareous sandstone and shale, as much as 200 feet thick (Peterson, 1957).	Unfavorable for gas storage.
Permian-Triassic	Redbeds	Spearfish--red shale and gypsum. Minnekahta--pink anhydritic limestone. Opeche--red shale and gypsum. All in Black Hills area; about 500 feet thick. Spearfish becomes anhydritic in central part of State, and in northwest. In Harding and Butte Counties the Spearfish is overlain by as much as 300 feet of Pine Salt, and that by 100 feet of Saude anhydrite and shale (Zieglar, 1956).	Possibility of leached cavities in Pine Salt for gas storage, in Harding and Butte Counties.

Table 1.--Generalized Stratigraphy of South Dakota with Reference to Underground Gas Storage--Continued

System	Smaller Stratigraphic Divisions	General Stratigraphic Information	Remarks Pertaining to Gas Storage
Permian-Triassic	Upper Minnelusa	Marine and brackish anhydrite, dolomite, limestone, and shale; Converse sandstones in northern Black Hills; thickness of upper Minnelusa about 450 feet.	Possibilities of gas storage locally in northern Black Hills in Converse sandstones.
Pennsylvanian	Lower Minnelusa	Marine and brackish limestone, dolomite, anhydrite, red and black shale, and lenticular sandstones (Leo in Black Hills area); thickness 200-800 feet, greatest in southwestern part of Black Hills. "Tyler" sandstone up to 350 feet thick in central South Dakota.	Unfavorable in Leo sandstones because of lenticularity. Possibilities of gas storage locally in "Tyler" sandstone in central part of State, which is potentially oil-bearing (Foster, 1960).
Mississippian		Madison--marine limestone and dolomite, with some anhydrite, in northwestern half of State; thickness as much as 700 feet.	Probably favorable because of great artesian pressure; it is a good source of fresh to brackish water.
		Englewood--marine limestone, about 60 feet thick in Black Hills area.	Unfavorable for gas storage.
Devonian		Three Forks--marine shale and shaly limestone; thickness as much as 40 feet; in northwestern corner of State. Birdbear, Duperow, Souris River--marine limestone and dolomite (Sandberg, Hammond, 1958); thickness as much as 325 feet; in northwestern quarter of State.	Unfavorable for gas storage

Table 1.--Generalized Stratigraphy of South Dakota with Reference to Underground Gas Storage--Continued

System	Smaller Stratigraphic Divisions	General Stratigraphic Information	Remarks Pertaining to Gas Storage
Silurian		Interlake--marine limestone, dolomite, with local red shale at unconformities (Ashern); thickness as much as 375 feet; in northwestern part of State.	Unfavorable because of lack of adequate seal.
Ordovician	Upper Ordovician	Stony Mt.--marine limestone and calcareous shale, in northwestern part of State; thickness as much as 165 feet.	Unfavorable because of lack of adequate seal.
		Red River--marine dolomite and limestone with three zones of water and oil in Harding County but with low gas pressure; as much as 590 feet thick; in western two-thirds of State. (Viola limestone and dolomite in southeastern corner of State).	Possibly favorable for gas storage in Buffalo Oil Field in northwestern corner of State. Source of fresh and brackish water in northwestern and central parts of State.
	Middle? and Upper Ordovician	Winnipeg--marine shale and siltstone, as much as 350 feet thick. Marine sandstone below, as much as 140 feet thick; in most of State; (Simpson shale, siltstone and sandstone in southeastern corner of State).	Shale unfavorable. Sandstone flows fresh and brackish water from 8500 feet in Harding County; possibly favorable for gas storage. Simpson sandstone has oil shows in southeastern corner of State.
Ordovician? - Cambrian	Lower Ordovician? and Upper Cambrian	"Deadwood"--marine sandstone, shale, dolomite; as much as 565 feet thick; in most of State.	Probably unfavorable because of irregular permeability.
Precambrian		Granite, quartzite, metamorphic rocks; granite underlies the other lithologies, and is overlain by several thousand feet of Sioux quartzite in southeastern quarter of State.	Possibility of mined cavities in granite where not too fractured, where overlain with impermeable seal, and where not too deep.