UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

THICK SEQUENCES OF SILICATE AND CARBONATE ROCKS OF SEDIMENTARY ORIGIN IN NORTH AMERICA

AN INTERIM REPORT*

By

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ABSTRACT

Thick sequences of silicate and carbonate rocks of sedimentary origin have been investigated in 64 areas in North America. The areas containing the thickest and most homogeneous stratigraphic sections more than 1,000 feet thick, buried at depths greater than 10,000 feet are:

1. Uinta Basin, Utah, where the Mancos shale is 1,300 to 5,000 feet thick, the Weber sandstone is 1,000 to 1,600 feet thick, and Mississippian limestones are 1,000 to 1,500 feet thick.
2. Washakie Basin, Wyoming, and Sand Wash Basin, Colorado, where the Lewis shale is 1,000 to 2,000 feet thick and the Cody-Mancos shale is 4,500 to 5,500 feet thick.
3. Green River Basin, Wyoming, where the Cody-Hilliard-Baxter-Mancos shale sequence averages more than 3,000 feet, the siltstone and shale of the Chugwater formation totals 1,000 feet, and the Madison limestone ranges from 1,000 to 1,400 feet thick.

4. Red Desert (Great Divide) Basin, Wyoming, where the Cody shale is 4,000 feet thick.
5. Hanna Basin, Wyoming, where the Steele shale is 4,500 feet thick.
6. Wind River Basin, Wyoming, where the Cody shale is 3,600 to 5,000 feet thick.

Geochemical characteristics of these rocks in these areas are poorly known but are being investigated. A summary of the most pertinent recent analyses is presented.

INTRODUCTION

The scope of an investigation of silicate and carbonate rocks in North America is so broad that the following arbitrary limits were established in order to concentrate research along lines most effective for the proposed experiments:

1. Human geography, geopolitics, and broad economic considerations suggest that it is not practical, for the purpose of this investigation, to consider in detail any areas east of the 96th meridian. Such areas were, however, studied in a general way in order to be certain that none with outstanding stratigraphic and structural attributes were overlooked.
2. Hypothetical safety conditions suggest that areas in which silicate and carbonate rocks have less than 10,000 feet of cover should not be considered at the present time.
3. Only those silicate and carbonate sequences that are relatively homogeneous and more than 1,000 feet thick are of interest in the current phase of investigation.

One of the serious deficiencies in data is the small number of detailed chemical analyses of silicate and carbonate rocks of sedimentary origin. Clarke (1915) presents analyses of rocks and minerals from the laboratory of the U. S. Geological Survey from 1880 to 1914 and Butler (1915) gives analyses of clays from Colorado. W. W. Rubey of the Geological Survey is now making a compilation of chemical analyses of rocks in the United States from all available published sources. Nearly all the analyses are for SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, H_2O, TiO_2, and CO_2. Very few analyses contain data on more than 12 elements or combinations of elements, and of those that do, only a small proportion are from thick sequences of silicate and carbonate rocks of sedimentary origin in or around the margins of deep structural basins.

Geochemical studies are now in progress. H. A. Tourtelot of the Geological Survey provided analyses of 17 samples of the Pierre shale of Late Cretaceous age in eastern Wyoming and adjacent areas. This shale is several thousand feet thick and is a partial lateral equivalent of the thick shale that is of major interest in several basins to the west. Tourtelot (personal communication) states:

> "The average composition (and standard deviations) of the 17 samples of shale is SiO_2--59.68 (3.59), Al_2O_3--15.40 (1.56), Fe_2O_3--4.56 (1.12), FeO--0.96 (0.66), MgO--2.11 (0.49), CaO--1.52 (1.15), Na_2O--1.09 (0.43), K_2O--2.49 (0.27), H_2O minus--3.73 (1.12), H_2O plus--4.77 (0.86), TiO_2--0.60 (0.06), CO_2--0.87 (1.34), P_2O_5--0.15 (0.05), SO_3--0.85 (0.98), Cl--0.01, F--0.07, S--0.21 (0.19), MnO--0.19 (0.41), BaO--0.08 percent."

The present study is part of a program that the U. S. Geological Survey is conducting in connection with its Investigations of Geologic Processes project on behalf of the Division of Research, U. S. Atomic Energy Commission.

AREAS UNDER INVESTIGATION

Figure 1 shows the areas that were investigated. Numbers on this figure correspond to the following numbered areas:

1. Newfoundland
2. Maritime Appalachians
3. New England and Central and Southern Appalachians
4. Eastern Triassic Basins
5. Atlantic Coastal Plain
6. Florida
7. Andros Island
8. Michigan Basin
9. Illinois Basin
10. Alabama
11. Mississippi
12. Louisiana
13. Tyler (East Texas) Basin
14. Texas Gulf
15. Midland Basin
16. Delaware Basin
17. Mexico
    - A. Sabinas Basin

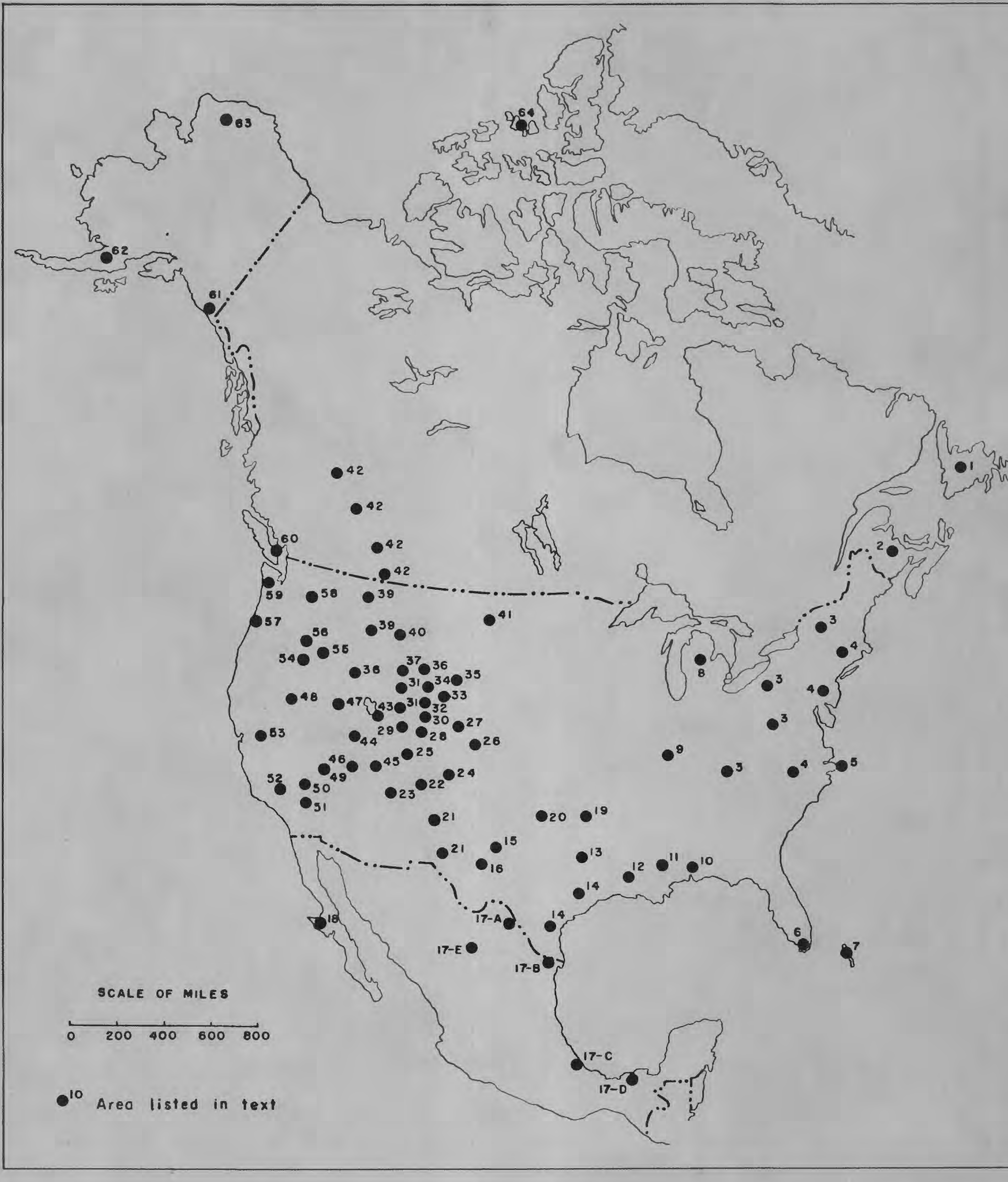

Figure I.— Index map of North America showing areas investigated for thick sequences of silicate and carbonate rocks of sedimentary origin.

B. Burgos Basin

C. Veracruz Embayment

D. Tabasco Reentrant

E. Parras Basin

18. Lower California

19. McAlester-Arkansas Basin, Oklahoma

20. Anadarko Basin, Oklahoma

21. Rio Grande Basins, central and southern New Mexico

22. San Juan Basin, New Mexico

23. Black Mesa Basin, Arizona

24. San Luis Basin, Colorado

25. Paradox Basin, Utah

26. Denver Basin, Colorado

27. North Park, Colorado

28. Piceance Basin, Colorado

29. Uinta Basin, Utah

30. Washakie Basin, Wyoming, and Sand Wash Basin, Colorado

31. Green River Basin, Wyoming

32. Red Desert (Great Divide) Basin, Wyoming

33. Hanna Basin, Wyoming

34. Wind River Basin, Wyoming

35. Powder River Basin, Wyoming

36. Bighorn Basin, Wyoming

37. Jackson Hole, Wyoming

38. Snake River Downwarp, Idaho

39. Western Montana

40. Crazy Mountains syncline, Montana
41. Williston Basin, North Dakota
42. Western Alberta and eastern British Columbia
43. Salt Lake-Utah Lake Basin
44. Confusion Range, Utah
45. Kaiparowits Basin, Utah
46. Southwestern Utah
47. Elko-Humboldt Basin area, northeastern Nevada
48. Carson-Black Rock system of intermontane basins, northwestern Nevada
49. Muddy Creek Basin area, southern Nevada
50. Central-eastern California
51. Mojave Desert, California
52. San Joaquin Valley, California
53. Sacramento Valley, California
54. Harney Basin, Oregon
55. Snake River Plains, Oregon
56. Central Oregon
57. Tertiary marine basin, Oregon
58. South-central Washington
59. West Coast of Washington
60. Georgia Basin (Vancouver Island area)
61. Katalla-Yakataga area
62. Cook Inlet-Alaska peninsula
63. Northern Alaska
64. Arctic Islands

AREAS OF MAJOR INTEREST

For the purposes of the proposed experiments, some areas are of much greater interest than others. The following areas shown on figure 1 are of major interest: 29, 30, 31, 32, 33, and 34.

Area No. 29, Uinta Basin, Utah

The Uinta Basin is a broad simple structural basin in which several silicate and carbonate sequences more than 1,000 feet thick lie at depths greater than 10,000 feet within an area of 600 square miles. The most significant rock unit is the Mancos shale, 1,500 feet thick in the western part of the area and 5,000 feet thick in the eastern part. This shale is remarkably homogeneous except near the top, where it intertongues with sandstone. The remainder, as much as 4,000 feet in the eastern part of the area, is gray soft slightly calcareous marine shale. Electric and radioactivity logs and studies of drill cuttings confirm the homogeneity observable on surface outcrops.

The Weber sandstone of Pennsylvanian age (1,000 to 1,600 feet thick) and Mississippian limestones (1,000 to 1,500 feet thick) are likewise of interest because they are at greater depth and underlie an area larger than 600 square miles. However, they are much thinner, not as homogeneous, and are poorly known at depths below 10,000 feet. The population in the Uinta Basin is sparse and there are few industrial establishments in the deepest part.

Area No. 30, Washakie Basin, Wyoming and Sand Wash Basin, Colorado

The Washakie Basin is in southwestern Wyoming and the Sand Wash Basin is in northwestern Colorado. These two names apply to parts of a major downwarp area that is divided approximately along the state line by a zone of east-trending normal faults and by the Powder Wash anticline southwest of the west end of the fault zone. Two formations are of interest, the Lewis shale, 1,000 to 2,000 feet thick, and the Cody-Mancos shale, 4,500 to 5,500 feet thick. The Lewis shale is thicker in the Sand Wash Basin, and is remarkably homogeneous, as indicated by electric logs, drill cuttings, and outcrop studies. The Lewis consists of soft dark gray marine shale. Sandstone beds intertongue with the upper 300 feet or more of shale in the northwestern part of the area.

The Mancos shale looks very much like the Lewis but is homogeneous throughout more than 3,000 feet. Sandstones intertongue with the upper several hundred feet of beds in the northern and western parts of the area. Sparse limestone beds, 5 to 10 feet thick, are present near the base in the eastern part of the area.

The Lewis shale lies at depths greater than 10,000 feet in an area of at least 500 square miles in the Washakie Basin. There is not adequate control in the Sand Wash Basin, but the area in which the Lewis shale is below 10,000 feet is thought to be greater than in the Washakie Basin. Inasmuch as the Mancos shale lies 2,000 to 4,000 feet below the Lewis shale, the area in which the Mancos is below 10,000 feet is much larger than that for the Lewis.

Within the area of interest, in the Washakie Basin there are virtually no inhabitants and no industries. Nearly every alternate square mile in the northern part of this basin is owned by the Union Pacific Railroad. The Sand Wash Basin contains a few more residents but is still very sparsely populated. The only industries in the deeper part of this basin are livestock and farming.

Area No. 31, Green River Basin, Wyoming

The Green River Basin is one of the most interesting of those that have been investigated because:

1. The area in which thick homogeneous rock sequences are at depths below 10,000 feet exceeds 4,500 square miles.

2. The Cody-Hilliard-Baxter-Mancos shale sequence averages more than 3,000 feet in thickness and is relatively homogeneous, the red and gray Chugwater formation (Triassic) consists of more than 1,000 feet of siltstone and shale with some limestone and is somewhat less homogeneous, and the Madison limestone (Mississippian) in the western part of the area is 1,000 to 1,400 feet thick and is relatively homogeneous.

3. Nearly all the area is either uninhabited or very sparsely settled. Coal, oil, gas, and livestock are the only industries, and the first three are, for the most part, concentrated near the basin margins.

4. Much of the land is federally owned and all of it is readily accessible.

Area No. 32, Red Desert (Great Divide) Basin, Wyoming

Within an area of about 2,000 square miles the Cody shale lies at a depth of 10,000 feet and in the northern and eastern parts may reach a depth of 17,000 feet or more. The Cody shale is about 4,000 feet thick. The upper 1,000 feet contains some sandstone lenses and sandy shale beds, but the lower 3,000 feet is soft gray calcareous marine shale. This is the only rock sequence of present interest in the basin. The entire area is essentially uninhabited except along the southeast margin where the Union Pacific Railroad has established maintenance stations. Nearly every alternate square mile for 20 miles north of the railroad is owned by the Union Pacific Railroad. Most of the remaining land is owned either by the Federal or State governments. The only industry is livestock.

Area No. 33, Hanna Basin, Wyoming

The Hanna Basin is one of the most remarkable basins in the Rocky Mountain Region, in that it is extremely deep with respect to its lateral extent. It is cup-shaped, about 40 miles across and perhaps 40,000 feet deep. About 400 square miles of the basin contains rocks of interest below depths of 10,000 feet. The Lewis shale is 2,000 to 2,500 feet thick and consists of homogeneous soft gray marine calcareous shale. The Steele shale (Cretaceous) is about 4,500 feet thick, and its top is at a depth of 20,000 to 30,000 feet in the deepest part of the basin. Some sandstones are present in the upper 1,000 feet, but the lower 3,000 feet of shale is relatively homogeneous, gray, marine, and calcareous. This area has no oil or gas fields and no industries except livestock and some coal mining. The Union Pacific Railroad owns nearly every alternate square mile in the basin. The main line of the Union Pacific Railroad, and U. S. Highway 30 traverse the southern, more shallow part of the basin. One town (Hanna, population 1,300) is on the railroad.

Area No. 34, Wind River Basin, Wyoming

The Wind River Basin is a broad asymmetric structural syncline with the trough line near the northern margin of the topographic basin. The Owl Creek Mountains have been shoved southward over much of the northern flank of the syncline. The Cody shale, 3,600 to 5,000 feet thick, is the only formation of interest. The upper 500 to 1,000 feet contains sandstones and siltstones, but the lower 2,500 to 4,000 feet is remarkably homogeneous soft gray marine calcareous shale. Through an area of more than 1,000 square miles the Cody shale is buried to depths of 10,000 feet and in places to 20,000 feet or more. The population is sparse, and the only industries in the deeper part of the basin are livestock and farming. Along the margins are oil and gas fields and uranium mines.

CONCLUSIONS

The present study is too incomplete to warrant specific recommendations, but on the basis of available data the most promising areas are the broad deep structurally simple downwarps in Wyoming, Colorado, and Utah (areas 29 to 34, inclusive, on figure 1).

California has vast thicknesses of sedimentary rocks, especially in the Sacramento and San Joaquin valleys, where the section is 10 miles thick. However, the high density of population and industry in this area is a serious drawback. Alaska has thick sections of sedimentary rocks; but in most of the geosynclinal areas the lack of adequate structural data, the fact that all but one major downwarp are along or near the coast, and the problems of severe climate and logistics make Alaska of secondary interest at the present time.