THE UPPER CRETACEOUS AND PALEOCENE STRATIGRAPHY OF TURTLE MOUNTAIN, MANITOBA

A Thesis

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ABSTRACT

The Turtle Mountain study area is situated on the northeastern rim of the Williston Basin, a negative structure on the craton. During the last Cretaceous marine transgression and regression, the Riding Mountain and Boissevain Formations were deposited. In the Paleocene, after a short erosional interval, deposition of Turtle Mountain Formation occurred.

The Riding Mountain Formation consists of three members. The Millwood Member, the lowest unit, is a soft, greenish-brown, bentonitic, slightly silty clay. The Odanah Member, the middle unit, is a hard, grey, siliceous, clay shale. The Coulter Member, as proposed in this paper, is the upper unit, a light grey to buff, bentonitic, fine-grained clayey silt. The Riding Mountain Formation is correlated with the Bearpaw Formation of Saskatchewan and the upper part of the Pierre Shale of North Dakota. All of these formations were deposited in less than 200 feet of water.

The overlying Boissevain Formation is composed of a thick lower unit of crossbedded, buff, quartz-rich, medium-grained, "salt and pepper" sand, and a thin upper unit of massive, white kaolinitic, fine-grained silt or clay. The Boissevain Formation is equated to the Fox Hills Formation of North Dakota and the Eastend, Whitemud, and Battle Formations of Saskatchewan. Deposition of the

Boissevain Formation occurred at the mouths of rivers which emptied into a basin. An easterly direction of sediment transport is indicated by crossbedding measurements in the Boissevain Formation.

The overlying Turtle Mountain Formation consists of two members, as proposed in this paper. The Goodlands Member, a lower assemblage of bentonitic, lignite-bearing sands, silts and clays, is correlated with the Hell Creek and Frenchman Formations of North Dakota and Saskatchewan, respectively. This member was deposited in a lagoonal environment. The Peace Garden Member, an upper assemblage of grey silty clays with minor greenish sand and silt beds, was deposited, for the most part, in a shallow water marine environment during readvance of the sea in the Paleocene. These marine beds are equivalent to the Cannonball Formation, a part of the Fort Union Group of North Dakota. The Peace Garden Member, as a unit, is correlated with the Fort Union Group and the Ravenscrag Formation of Saskatchewan.

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CHAPTER I

INTRODUCTION

AREA OF STUDY

The 1050 square mile, Turtle Mountain study area is located in southwestern Manitoba (Fig. 1). The area extends from Range 16 WPM to Range 24 WPM, and from the International Boundary to Township 4 North (Fig. 2). Within this area is the northern half of Turtle Mountain, an 800-foot high oval-shaped upland.

A mantle of Pleistocene glacial drift and Recent sediments is draped over the Upper Cretaceous and Paleocene bedrock of the study area. Bedrock exposures are few and are primarily confined to roadcuts and deep ravines on the western and northern flanks of Turtle Mountain. It was from these bedrock exposures that sandstone was quarried in the late 1800's for use in the construction of buildings. Lignite was mined intermittently in the Turtle Mountain area from 1879 to 1943.

OBJECTIVES AND METHODS OF INVESTIGATION

The objectives of this thesis are to describe the Upper Cretaceous and Paleocene stratigraphy of the study area, to correlate strata across the study area and into adjacent regions, and to interpret the history of sedimentation. To accomplish these objectives a combination

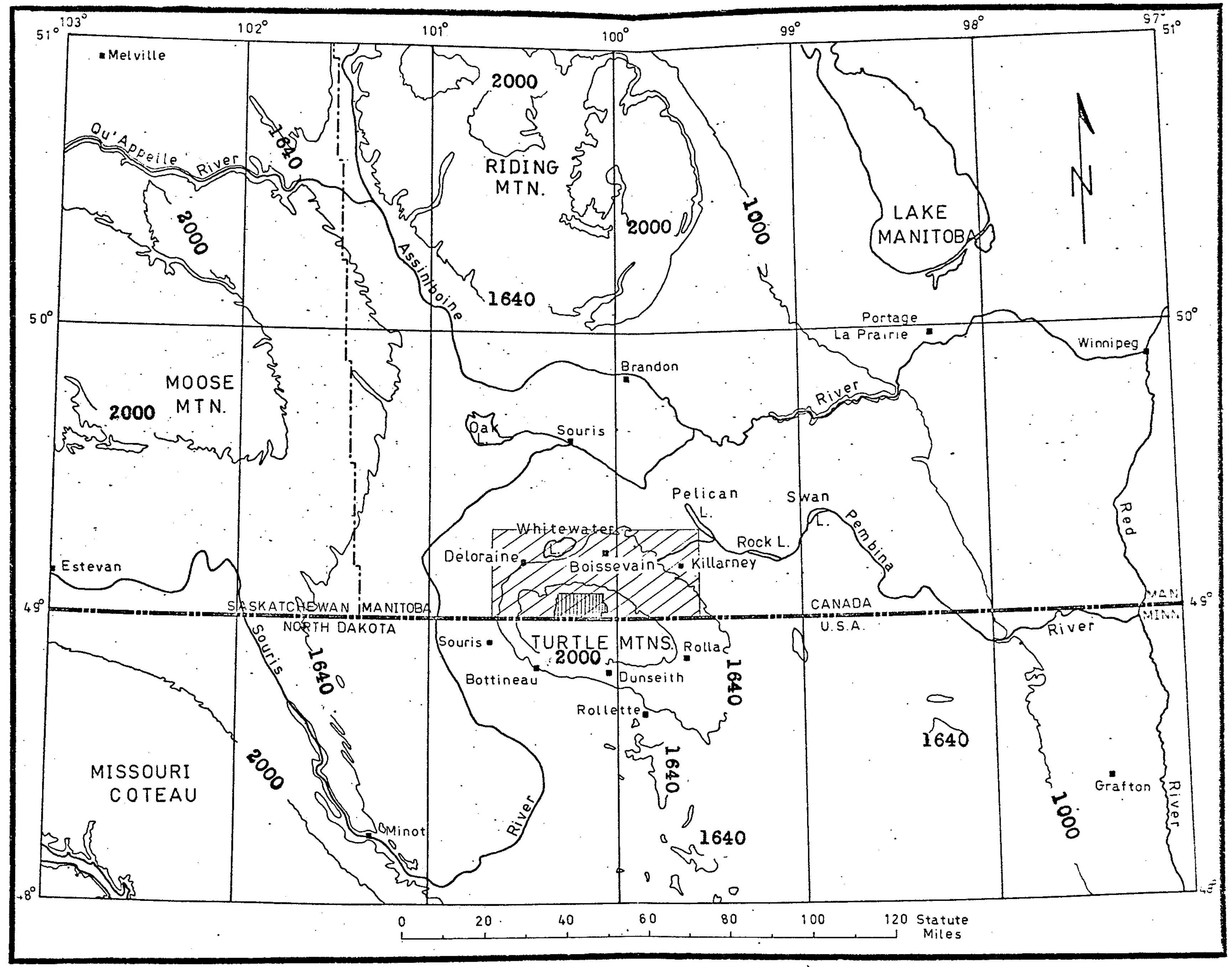


Figure 1. Index map for the Turtle Mountain study area (diagonal cross-hatching) showing Turtle Mountain Provincial Park (vertical cross-hatching). Topographic contours drawn at 1000, 1640, and 2000 feet above sea level.

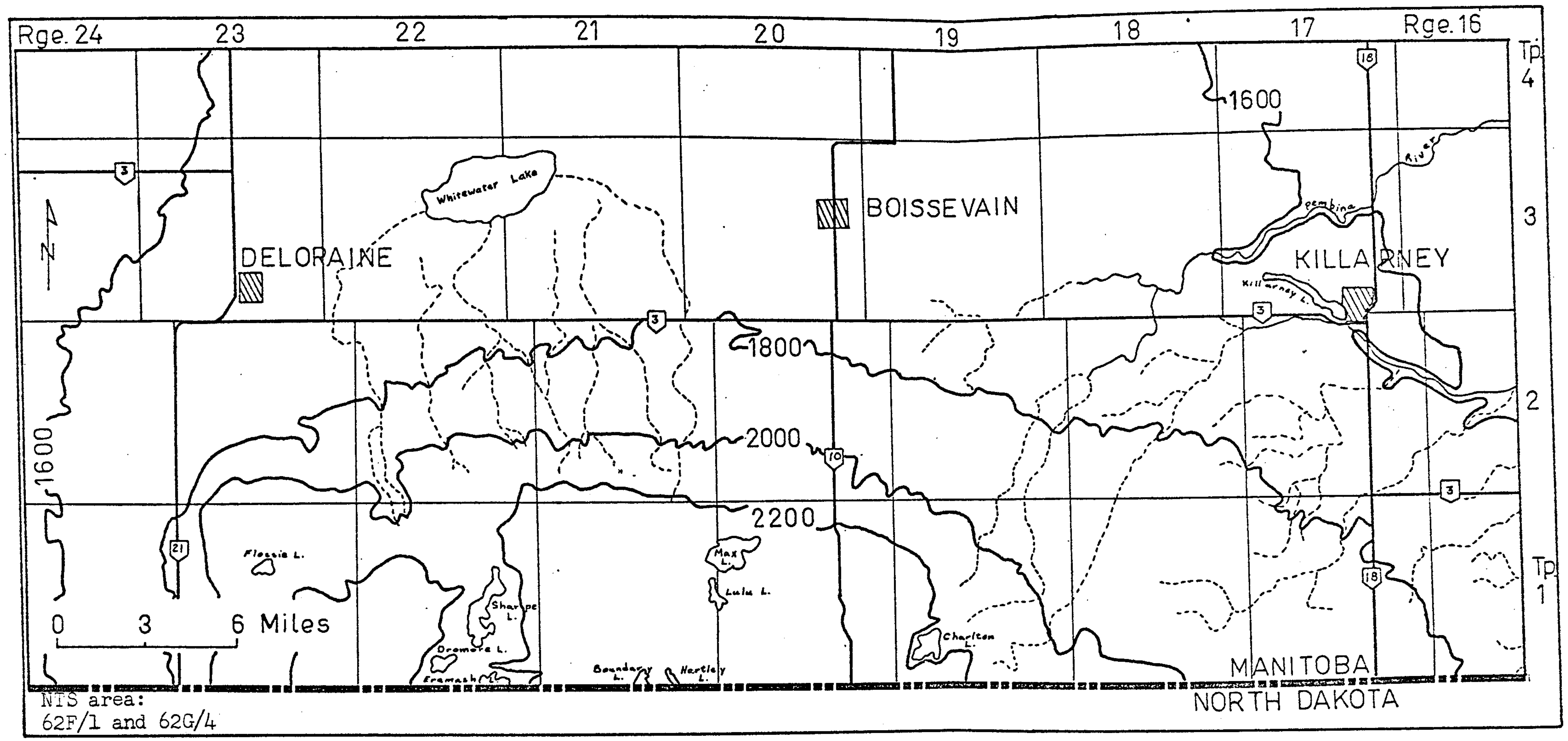


Figure 2. Turtle Mountain study area. Topographic contour interval, 200 feet.

of field work and laboratory study was completed.

During the 1971 field season bedrock exposures in the study area (Fig. 3) were described and sampled; preliminary lithologic logs were constructed on-site from three Manitoba Mines Branch cored drill holes; and field trips were made into North Dakota and Saskatchewan.

Samples from outcrops and drill holes collected in the study area are stored in the Manitoba Mines Branch core and sample library.

To distinguish between formations (and constituent members) the grain size, mineralogy, and electric log characteristics were studied. Procedures of sieving analysis and methods of textural parameter calculation followed are those of Folk (1968, p. 32-52). Wentworth size classes are used to describe the sediments. The mineralogy of the samples was determined under a microscope and through the use of X-ray diffractograms made at the Department of Earth Sciences, University of Manitoba. The resistivity and spontaneous potential of 52 electric logs, together with gamma and neutron radiation curves, where available, were used to define the nature of the formations and their contacts in the subsurface. Isopach and structure contour maps were prepared mainly from this information. Locations of drill holes are shown in figure 3.

Crossbed measurements were used to determine mean paleocurrent directions according to the formulas of Potter and Pettijohn (1963, p. 254).

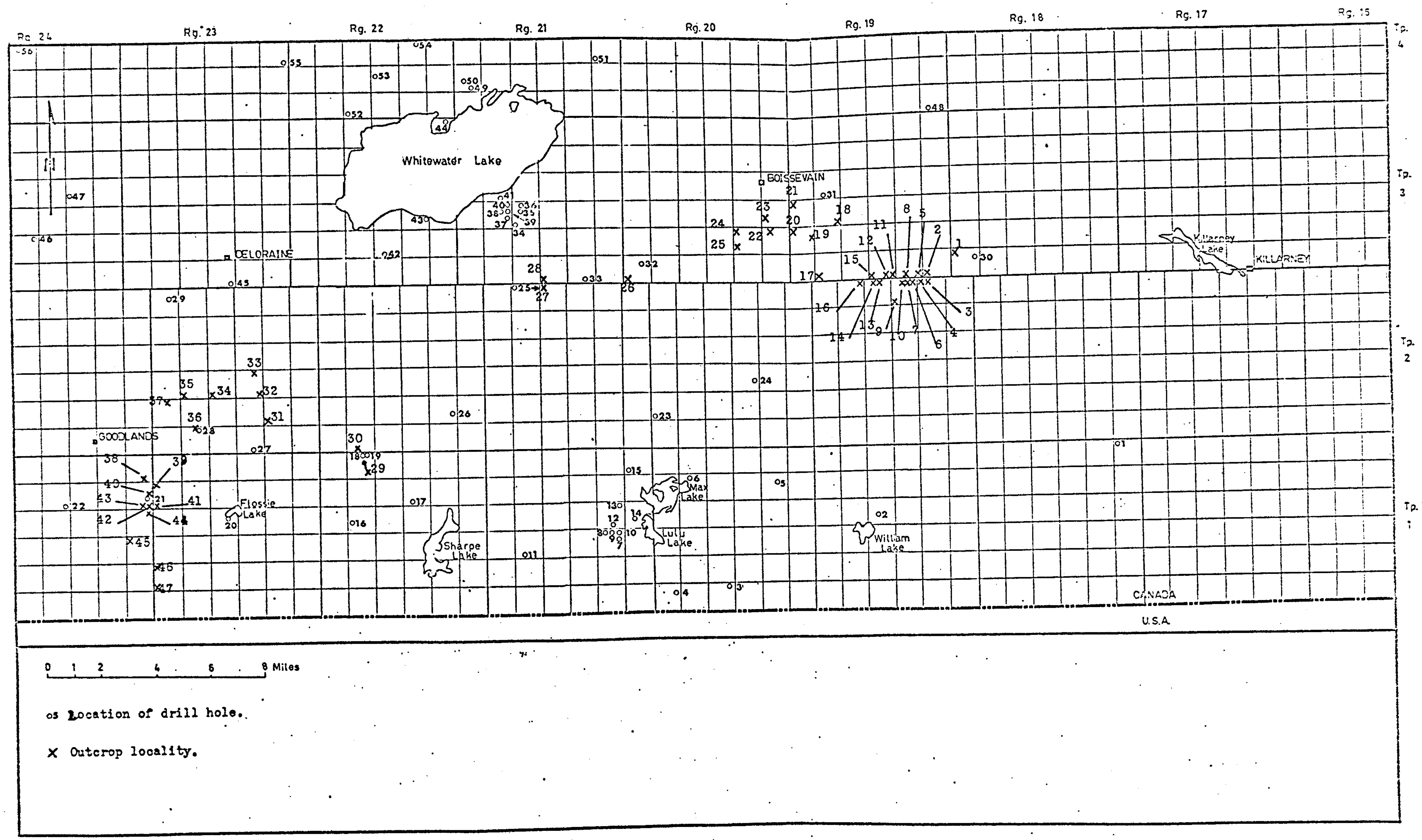


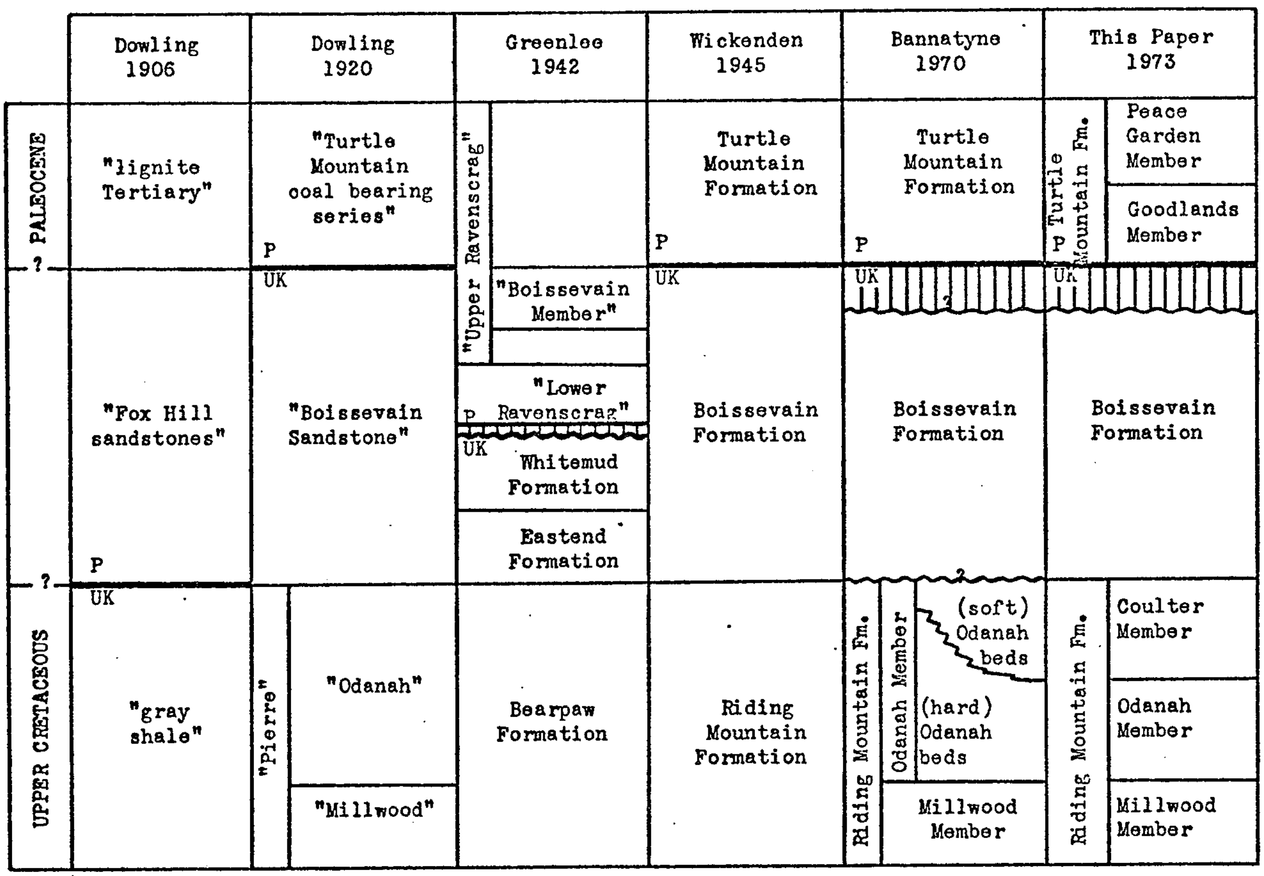
Figure 3. Outcrop and drill hole location map.

B. R. North at the University of Saskatchewan at Saskatoon conducted a micropaleontological study on samples, collected from outcrops and six drill holes, to determine their depositional environment and relative age.

PREVIOUS WORK

In the study area, 3000 feet of post-Paleozoic sediments were deposited on the Mississipian erosion surface (McCabe, 1963). Mesozoic and Cenozoic formations are a sequence of shale and sandstone ranging in age from Jurassic to Paleocene (Wickenden, 1945). The stratigraphic nomenclature of beds deposited during the Late Cretaceous to Paleocene interval has been revised many times (Fig. 4). Locally derived formation names and those of North Dakota and Saskatchewan have been used. Because of a lack of fossil evidence and correlation solely on the lithologic similarities to formations in North Dakota and Saskatchewan, the position of the Paleocene/Upper Cretaceous contact has been in dispute (Fig. 4).

Dowling (1906) was the first to describe the bedrock of the Turtle Mountain area. He placed the Paleocene/Upper Cretaceous contact between a "gray shale" and a sand unit which he correlated with the Fox Hills Formation of North Dakota. Lignite-bearing sediments were placed with some reservation into the "lignite Tertiary". In 1920 Dowling updated his previous nomenclature, renaming the "gray shale" as the "Pierre" (after Tyrrell, 1890, p. 230), the



P/UK indicates Paleocene/Upper Cretaceous contact as proposed by various authors.

Figure 4. Evolution of the stratigraphic nomenclature of the Turtle Mountain area.

sand unit as the "Boissevain Sandstone" (after Parks, 1914), and the "lignite Tertiary" as the "Turtle Mountain coal bearing series". The Paleocene/Upper Cretaceous contact was elevated to a position between the "Boissevain Sandstone" and the "Turtle Mountain coal bearing series".

The geology of the North Dakota portion of Turtle Mountain was described by Greenlee (1942). The Manitoba portion was commented upon only briefly; however, the nomenclature and position of the Paleocene/Upper Cretaceous contact adopted by Greenlee was that used in Saskatchewan by Fraser et al (1935). The "gray shale" of Dowling (1906) was called the "Bearpaw" by Greenlee. He placed the Boissevain as a member high in the Ravenscrag Formation.

Wickenden (1945) applied the name Riding Mountain Formation to the "gray shale" of Dowling (1906), and regarded the "Odanah" of Tyrrell (1890) as only a "peculiar lithologic phase". The "Boissevain Sandstone" of Parks (1916) was renamed the Boissevain Formation by Wickenden (1945, p. 50) and he reported that Kirk had renamed the "Turtle Mountain coal bearing series" of Dowling (1920) as the Turtle Mountain Formation. The Paleocene/Upper Cretaceous contact was placed between the Boissevain and Turtle Mountain Formations by Wickenden (1945).

The nomenclature and position of the Paleocene/Upper Cretaceous contact of Wickenden (1945) was retained by Bannatyne (1970); however, Bannatyne used Tyrrell's (1890) subdivisions, the "Odanah" and "Millwood", as members of the Riding Mountain Formation. Bannatyne also subdivided the Odanah Member into an upper "soft Odanah" and lower "hard Odanah".

The last column in Figure 4 shows the nomenclature used throughout this thesis and the position proposed for the Paleocene/Upper Cretaceous contact.

ACKNOWLEDGEMENTS

I would like to thank the Manitoba Mines Branch, my employers during the 1971 field season, for permission to use data collected within the Turtle Mountain study area for my thesis. Acknowledgements are due also to the National Research Council and the University of Manitoba for a graduate assistantship. Much advice came from E. I. Leith and J. T. Teller (Department of Earth Sciences, University of Manitoba) and B. B. Bannatyne (Manitoba Mines Branch), my advisors for this thesis.

Special thanks are directed to the Geological Survey of Canada and the Manitoba Mines Branch for the use in petrological and micropaleontological studies, of drill hole samples from the Turtle Mountain area. My appreciation is extended to W. G. E. Caldwell and his associates, in particular B. R. North, at the University of Saskatchewan who conducted micropaleontological studies for this thesis.

Assistance and information in the field were obtained from D. W. Deal and S. R. Moran of the North Dakota Geological Survey, G. Lammers of the Manitoba Museum of Man

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CHAPTER II

STRATIGRAPHY OF THE RIDING MOUNTAIN FORMATION

DEFINITION AND DESCRIPTION OF FORMATION

Within the study area, the Riding Mountain Formation is generally a 950-foot thick assemblage of grey marine clays occurring between the marine Upper Cretaceous Vermilion River Formation and the overlying Upper Cretaceous Boissevain Formation.

The formation is composed of three major lithologies: a lower unit of slightly silty clay, the Millwood Member; a middle unit of clay shale, the Odanah Member; and an upper unit of clayey silt, the Coulter Member (Fig. 4).

DEFINITION AND DESCRIPTION OF MEMBERS

Millwood Member

The Millwood Member of the Riding Mountain Formation is a soft greenish brown bentonitic slightly silty clay occurring between the Vermilion River Formation and the overlying Odanah Member of the Riding Mountain Formation.

The type locality of the Millwood Member (Tyrrell, 1890) is located about 120 miles northwest of Turtle Mountain in the Assiniboine River Valley at Millwood, Manitoba. A type section has not been described for the Millwood Member.

The Millwood Member is not exposed at the surface in the study area. In the subsurface, the thickness of this member ranges from 75 feet in the southeast to 250 feet in the northwest (Bannatyne, 1970, p. 57). In chip samples the Millwood Member is a bentonitic slightly silty clay composed mainly of partly swelling montmorillonite. The chips have a "popcorn" or "cauliflower" surface which is characteristic of the Millwood Member where it has been mixed with water during drilling or exposed to weathering at the surface.

The upper contact of the Millwood Member with the overlying Odanah Member is placed at the abrupt lithologic change between the distinctive soft greenish brown bentonitic slightly silty clay and the overlying hard grey siliceous clay shale. This contact is clearly recognizable in chip samples and on gamma-ray and resistivity curves. Bentonite absorbs heavy radioactive elements (Lynch, 1962) and its presence in the highest Millwood beds would account for their higher radioactivity. The upper contact was chosen as a stratigraphic datum for correlation between drill holes across the Turtle Mountain area (Fig. 5).

Odanah Member

The Odanah Member is the middle member of the Riding Mountain Formation. This hard grey siliceous clay shale member occurs between the Millwood Member and the overlying Coulter Member of the Riding Mountain Formation.

The type locality of the Odanah Member (Tyrrell, 1890) is approximately 80 miles north of Turtle Mountain, at the

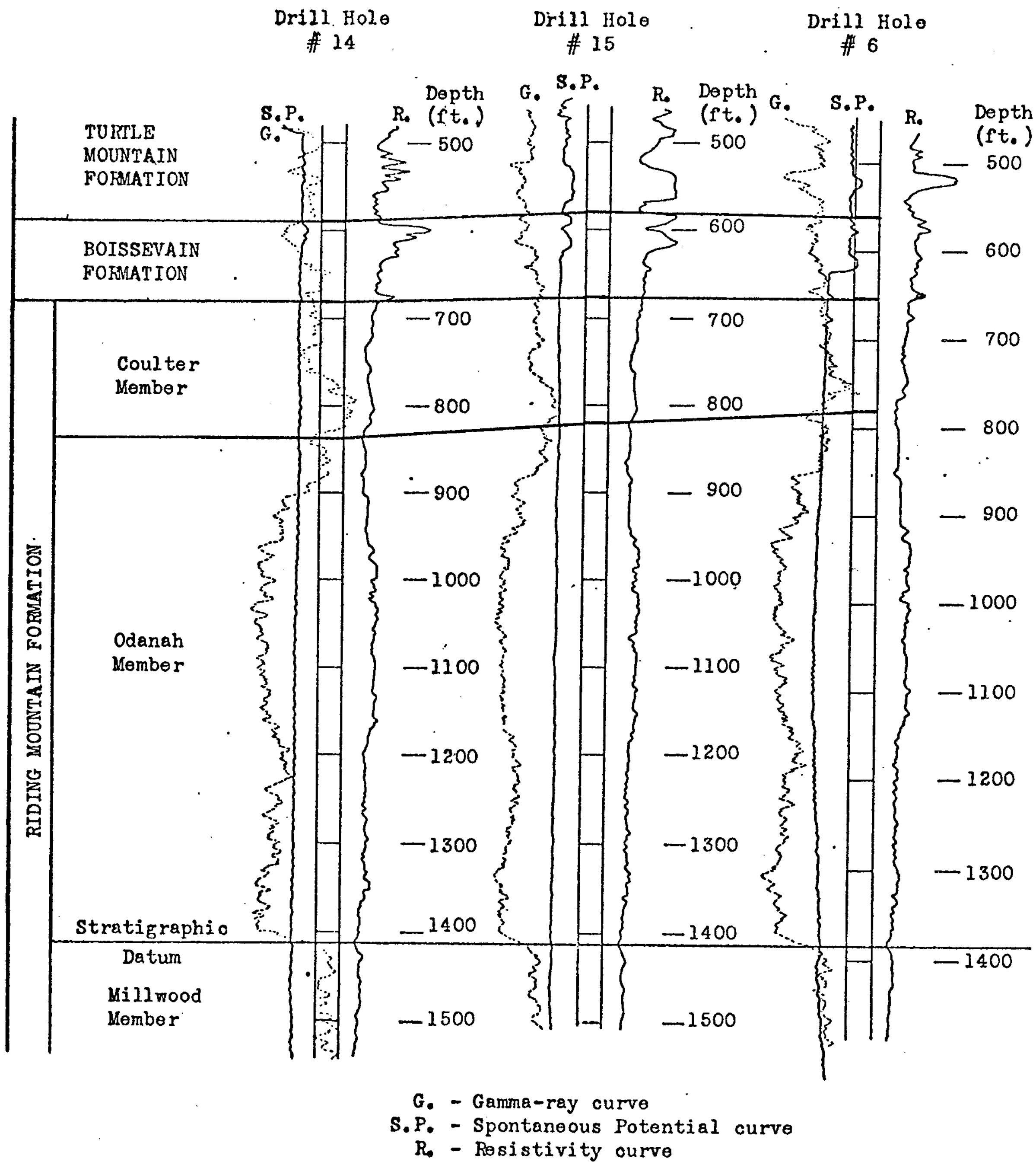

Figure 5. Correlation between drill holes by means of radioactivity, spontaneous potential, and resistivity logs.

abandoned village of Odanah, near Minnedosa, Manitoba. A type section has not been described for the Odanah Member.

The Odanah Member is not exposed at the surface in the study area. In the subsurface its thickness increases from 560 to over 640 feet radially outward from the center of Turtle Mountain. Chip samples of the Odanah Member show that it is siliceous, and it is steel grey when dry and dark greenish grey when moist. Many of the chips are stained a reddish to purplish brown colour. In outcrop, just outside the Turtle Mountain area at Dand, 8 miles north of Deloraine, and at Ninette, 16 miles north of Killarney, the Odanah Member appears as thin fissile beds and/or thick beds with conchoidal fracture.

With the exception of its uppermost beds, the Odanah Member has the highest resistivity and the lowest radioactivity of the three members of the Riding Mountain Formation (Fig. 5). The low radioactivity within the lower beds is attributed to its siliceous composition which prevents the absorption of heavy radioactive elements.

The hard grey siliceous shale of the Odanah Member grades into the overlying light grey to buff clayey silt of the Coulter Member within a stratigraphic interval of about 50 feet. The base of the interval is usually marked by the presence of a thin bentonite bed, an increase in radioactivity, and a decrease in resistivity (Fig. 5). The top of the interval is indicated by the absence of the hard grey siliceous shale, another increase in radioactivity and