MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

MINERAL RESOURCES DIVISION

MINERAL EVALUATION AND ADMINISTRATION BRANCH

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SUMMARY OF AVAILABLE DATA ON LIGNITE DEPOSITS, TURTLE MOUNTAIN, MANITOBA

(with a note on other occurrences in the Province)

by

B.B. Bannatyne

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ABSTRACT

Several thin beds of lignite, in quality equal to or lower than that mined in the Estevan area, are present at Turtle Mountain. The thickness of the beds ranges from several centimetres to less than two metres (a few inches to five or six feet). Although lignite occurs at several levels within the Paleocene Turtle Mountain Formation, only one or two seams of significant thickness are present.

Intermittent mining at several locations occurred between 1883 and 1908, and from 1931 to 1943. Maximum annual production was 4,113 tons. Some small-scale recovery by strip mining in the floor of some ravines was achieved. Mining operations, usually by adit into the side of ravines on Turtle Mountain, were of limited extent. Problems were encountered, such as discontinuity of the lignite beds, poor roof conditions because of the overlying sandy, silty beds, and groundwater in sand or sandstone beds. These conditions would make large-scale mining by room and pillar methods impractical.

Attempts were made in 1952 and again in 1955 and 1956 by West Canadian Collieries Limited to outline areas on the west slope of Turtle Mountain suitable for strip mining. The company concluded that thick overburden (including hard glacial drift) and lack of sufficient thickness of lignite would make strip mining uneconomical. Luscar Limited in 1972 explored both the western and northern slopes of Turtle Mountain, and reached the same conclusion.

Although recoverable reserves in the Turtle Mountain area have been estimated by B.R. MacKay (1946) at 16,800,000 short tons probable and an additional 33,600,000 tons possible (total probable and possible: 50,400,000 tons), the fundamental problem is that the nearly horizontal lignite beds occur at or near surface only where the topographic slope of the land is of the order of 19 to 37 m per km (100 to 200 feet per mile). Thus the ratio of overburden to lignite is generally too large to justify strip mining under present economic conditions. The slope is dissected by numerous ravines. Preglacial valleys on the northwest and northeast slopes of Turtle Mountain are filled with glacial deposits, thus eliminating those areas as potential mining sites. Consequently, based on the results of recent exploration, the resources of lignite recoverable by strip mining (assuming strip mining to be economical at some future date) are estimated at only a few million tons.

To date, no extensive areas with thin overburden over lignite of economic thickness have been outlined.

INTRODUCTION

Lignite seams from several centimetres to 1.6 or 1.8 m (a few inches to 5 or 6 feet) in thickness occur in the Turtle Mountain area (Figure 1) in the Paleocene Turtle Mountain Formation. This formation is the eastward equivalent of the Ravenscrag Formation of southeastern Saskatchewan, from which lignite is recovered in the Estevan-Bienfait area. The geological formations of the area are listed in Table 1.

This report summarizes information on the early lignite operations contained in reports by Selwyn (1893), Dowling (1906), Cameron (1949), Wright (1951) and Doerksen (1971), and in annual reports of the Manitoba Mines Branch (1931 to 1944).

Also, results of four exploration programs between 1952 and 1972, by West Canadian Colleries Limited, C.F. Doerr, and Luscar Limited are summarized, and are correlated with results of recent geological mapping of the Turtle Mountain area by Bannatyne (1966, 1970) and Bamburak (1973).

Geological History

Depositional environments in the Turtle Mountain area, as postulated by Bamburak (1973), fluctuated from marine to littoral during the Upper Cretaceous-Paleocene interval.

The silt and clay of the upper part of the Riding Mountain Formation, the Coulter Member, were deposited during the recessional stage of the major Upper Cretaceous marine invasion of central North America. Water depths were probably less than 61 m (200 feet), and the upward increase in size of clastic grains within the Coulter Member may reflect a further decrease in the water depth.

The Boissevain Formation is believed to have been deposited at the mouths of rivers during a transitional environment as the shoreline of the Cretaceous sea regressed westward. The sea finally withdrew from the area during a period of uplift.

The fluctuating conditions continued into Paleocene time, and shallow marine conditions prevailed at least during part of the time of deposition of the silt and clay of the lower part of the Goodlands Member. However, the lignite seams and disseminated plant fragments within clayey and silty sand suggest that stagnant basins were present. Plant remains accumulated and were preserved within the swampy basins, and were eventually converted to lignite.

Marine seas again transgressed the area, and the sandstone and shale of the Peace Garden Member were deposited. Water depths were shallow, as indicated by the unusually small size, poor preservation and paucity of the foraminifera and by the disseminated flecks of plant remains. The Paleocene seas then withdrew from central North America, and the area has since been subjected to subaerial erosion and Pleistocene glaciation.

Geological correlation with the strata of southeastern Saskatchewan is known in general (Table 1), but specific time-stratigraphic boundaries are not known precisely.

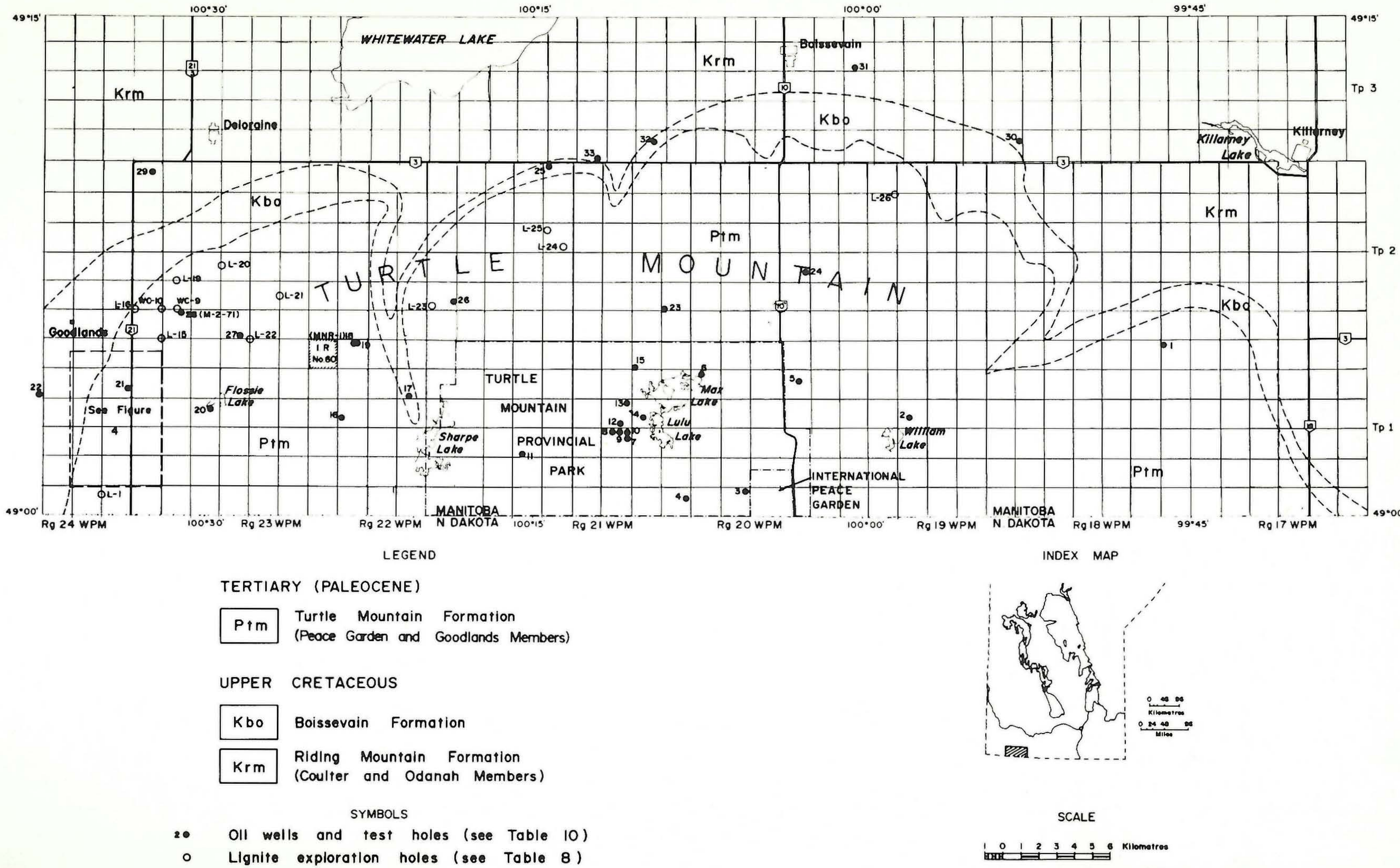

Figure 1. Turtle Mountain area and drill hole locations

Table 1

Correlation of Geological Formations

	Manitoba (after Bamburak, 1973)		Southeastern Saskatchewan
Pleistocene	Glacial drift		Glacial drift
Paleocene	Turtle Mountain Formation	Peace Garden Member	Ravenscrag* Formation
		Goodlands Member*	? Frenchman Formation
Upper Cretaceous	Boissevain Formation		Whitemud Formation
			Eastend Formation
	Riding Mountain Formation	Coulter Member	Bearpaw Formation
		Odanah Member	
		Millwood Member	

* Main lignite beds occur near the base of the Paleocene formations.

Former lignite operations

Doerksen (1971, p. 2) reported that the first discovery of lignite in the Turtle Mountain area was made in 1879, in 3-2-19WPM, (section 3, township 2, range 19 west of Principal Meridian). A 0.9 m (3 foot) seam of lignite was intersected there at a depth of 9.1 m (30 feet) in a well near the Boundary Commission Trail. Available information on the early period of lignite mining (1883 to 1908), and the main period of production (1931 to 1943), is listed in Table 2. The locations of the mines are shown in Figure 2.

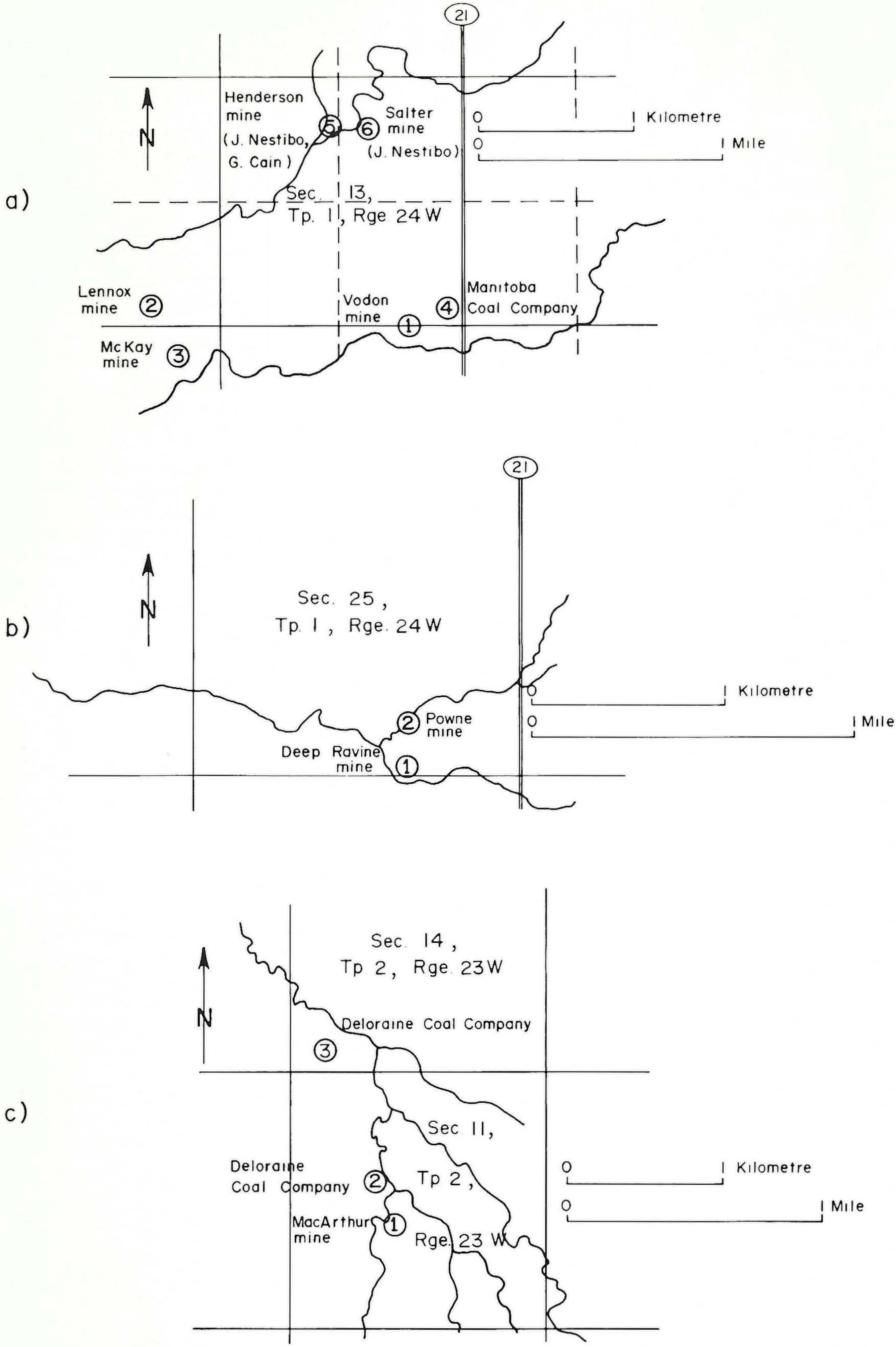

Figure 2. Location of former lignite operations at Turtle Mountain

Table 2

Former Lignite Operations

A. Early operations: 1883 to 1908

Mine, location, and references	*Remarks*
1. Lennox mine 2-14-1-24W; Locality 2, Figure 2a	First mined in 1883 (Wright, 1971). About 10 tons of lignite were removed.
2. Vodon (? Vaden)[1] mine (Selwyn, 1893, p. 11-12; Doerksen, 1971, p. 4-5) 16-12-1-24W Locality 1, Figure 2a	Mined in 1885. Two or possibly 3 seams of lignite occurred under the floor of a ravine 15 to 25 m (50 to 75 ft.) deep. The lignite was overlain by .9 m (3 ft.) of clay and 1.3 m (4 ft.) of till. A well was reported to have intersected 1.6 m (5.5 ft.) lignite, 3 m (10 ft.) shale, 1.1 m (3.5 ft.) lignite, 4 m (14 ft.) shale and sandy clay, .5 m (1.5 ft.) lignite, and 9.6 m (32 ft.) sand and sandstone. Selwyn (1893, p. 12) measured a second section showing two lignite seams, 1.3 m (4.5 ft.) and .5 m (1.5 ft.) thick. He states "the upper 5'6" seam of coal given in this first section is probably a mistake". A vertical shaft 12 m (40 ft.) deep was sunk, but water problems were encountered. Tunnels in the lignite caved in "before a reasonable amount of coal could be removed".
3. Manitoba Coal Co. (Doerksen, 1971, p. 17, 18) 1-13-1-24W and/or 12-1-24W (Vodon) Locality 4, Figure 2a	Operated 1889-1890. A shaft intersected 1.5 m (5 ft.) of lignite at a depth of 13 m (43 ft.). Another seam several feet thick was reported lower down. Drifting to the north showed a thickening of the seam; a boring in that direction had reported 2.7 m (9 ft.) of lignite. "You had to wring the water out of it before you could burn it". (Wright, 1951).
4. McArthur Mine (Selwyn, 1893; Dowling, 1906) 6-11-2-23W Locality 1, Figure 2c	Operated intermittently between 1893 and 1908. Several shallow pits were operated and then a 15 m (50 ft.) shaft was sunk to lignite, 1.5 to 1.8 m (5 to 6 ft.) thick, at a depth of 10.5 m (35 ft.). Either one seam, or two seams each .7 m (2.5 ft.) thick, were present, separated by up to .45 m (1.5 ft.) of clay. A third, thin seam was reported a short distance below, but not worked. The seams dip slightly to the north.
5. McKay Mine (Doerksen, 1971, p. 42) 16-11-1-24W Locality 3, Figure 2a	Operated in 1904. A small mine west of the Vodon mine.

B. Later mines: 1931 to 1943

6. Muir farm: Deloraine Coal Co. Ltd. (became Turtle Mountain Coal Mines in 1932) (Manitoba Mines Branch [MMB] Annual Reports for 1931, 1932) 11-11-2-23W (305 m [1000'] north of former McArthur mine) Locality 2, Figure 2c

In a 25° incline, lignite was intersected 3 m (10 ft.) below the floor of a ravine: .6 m (2 ft.) lignite, 1.6 m (5.5 ft.) sandstone and shale, .6 m (2 ft.) lignite. Dip of the lignite also was 25°, then it flattened to the west. One trench and one shaft were attempted, but no production was achieved. Another incline was started 45 m (150 ft.) northwest of the old McArthur mine. (Locality 1. Figure 2c). At 11.4 m (38 ft.) below the entrance, two seams pitching 14°N and 7°W. Upper: .3 m (10 to 12 ins.) lignite; .3 to .45 m (12 to 18 ins.) sand and clay; lower: .5 to .9 m (20 to 34 ins.) lignite. In places, the seams come together for 1.1 m (3.5 ft.) lignite. About 600 tons production in 1931. In 1932, two seams, each .75 m (2.5 ft.) thick and separated by .9 m (3 ft.) of sand and clay were worked, and 60 tons of lignite was removed. Other shafts and drifts failed to find lignite. (Press reports of two 1.5 m (5-foot) seams are not substantiated by MMB reports).

7. Henderson Mine
   a) John Nestibo: 1931-1932
   b) George Cain: 1933-1938
   c) Goodlands Mine Co.: 1939-1943

   (MMB Annual Reports 1931-1944; Cameron, 1949)
   14-13-1-24W
   Locality 5, Figure 2a

This was the major operation at Turtle Mountain. First operated as an open-cut in floor of ravine, with lignite at depth of 2.25 m (7.5 ft.). In 1932, 2.7 m to 5.1 m (9 ft. to 17 ft.) of overburden were removed, and 1,202 tons mined by opencut from main lignite seam .9 to 1.1 m (36 to 42 ins.) thick. In 1931, two adits on northwest side of ravine: .3 m (1 ft.) lignite, 0.15 m (0.5 ft.) black clay, 1.1 m (3.5 ft.) lignite. Operated to 1939. A sloping adit was driven from the surface, and the pillar and stall system was used. In 1939, a long entry was driven to the west, winning stalls to the south. In 1941, average thickness was 1.1 m (3.75 ft.) lignite; friable roof and overburden of soft shales and clay. New mine in 1943, .24 km (250 yards) southeast of former mine. A slope at 1 in 3 cut the seam at a depth of about 12 m (40 ft.) vertically below surface. In 1942, horse haulage was substituted underground for hand tramming. Operations ceased in 1943 because of shortage of labour.

8. McLeod or Deep Ravine Mine (Doerksen, 1971, p. 50-51; MMB Annual Report 1931) 15-24-1-24W Locality 1, Figure 2b

In 1931, an adit was driven 22 m (76 ft.) into the north bank: .8 m (34 ins.) lignite; caved in. A second adit, 16.5 m (55 ft.) to west, intersected coal at 8.5 m (25 ft.) into the bank; very little mined. In October 1932, Reine Rollins sank a shaft 45 m (150 ft.) east of the old workings. It intersected lignite at a depth of 7.5 m (25 ft.)

9. Hainsworth farm Deloraine Coal Mines (Doerksen, 1971, p. 117-121) 4-14-2-23W Locality 3, Figure 2c	An inclined drift was driven; no production.
10. Salter farm John Nestibo (MMB Annual Reports 1932-1938) 15-13-1-24W Locality 6, Figure 2a	Operated from 1932 to 1938. In 1932, lignite was recovered from an open pit, under 2.7 m (9 ft.) to 3.9 m (13 ft.) overburden. In 1933, two adits were driven north, from bottom of pit. In 1934, a slope was driven into east bank of ravine, and 1.1 m (3.5 ft.) lignite worked. In 1935, a shaft 9 m (30 ft.) deep was sunk, and the lignite worked by pillar and stall system. Water and subsidence conditions prevented continuation of operations in fall of 1938.
11. Powne farm (Doerksen, 1971, p. 85-86) 2-25-1-24W Locality 2, Figure 2b	Operated in 1933, possibly also in 1934. Only a small quantity of lignite was produced. An incline at a slope of 1 in 3 was driven into the creek bank, and .75 m (2.5 ft.) lignite, .45 m (1.5 ft.) clay, and .3 m (1.0 ft.) lignite were intersected. An attempt at strip mining was made in 1942 on the SW¼ of sec. 25, but no lignite was mined because of "adverse conditions".

Note: The locations of the former mines are plotted on three air photos in Doerksen (1971, p. 55, 70). The locations are shown in Figure 2 of this report.

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[1] In Selwyn's report (1893), the locality is called the Vaden mine. Doerksen (1971) reports a local resident as stating the correct spelling is Vodon.

Production figures

Two sets of production figures are available from Manitoba Mines Branch files. Some minor discrepancies are present, possibly the result of splitting figures from the fall to spring operating season into calendar year figures. Available information is listed in Table 3. Production figures for the years of operation between 1883 and 1908 are not available.

Table 3

Lignite Production in Manitoba: 1931-1943

	Production reported, by mine, in short tons							Official figures	
	Henderson (7)*	McLeod (8)	Powne (11)	Deloraine Coal Co (6)	Salter (10)	Total Tons	Total Value	Tons	Value
1931	700	200		450		1350	$4050	1306	$3797
1932	2100	423		60	250	2830	7075	2830	7075
1933	2149		70		1741	3960	9367	3960	9367
1934	2153		112		1848	4113	8952	4113	8952
1935	1944				1162	3106	7408	3106	7408
1936	2116				1913	4029	9525	4029	9525
1937	1933				1239	3172	7709	3172	7709
1938	1355				366	1721	5126	2016	5660
1939	1187					1187	3110	1138	3110
1940	1697					1697	4037	1697	4037
1941	1234					1234	3381	1246	3411
1942	1342					1342	?	1265	3763
1943	999					999	?	999	2964

* Numbers in brackets refers to corresponding number in Table 2.

Quality of the lignite

Analyses of lignite from the Turtle Mountain area, believed to be reliable, were quoted by Cameron (1949), and are reproduced in Table 4. An analysis of lignite, from the Henderson Mine, is reported by Swartzman (1953). Results are summarized in Table 5.

Table 4

Typical Seam Analyses

	Deloraine Coal Mine		Henderson Mine		McLeod Mine	
	As Received	*Air Dried*	*As Received*	*Air Dried*	*As Received*	*Air Dried*
Moisture (%)	38.67	17.12	35.45	15.40	38.52	18.03
Volatile matter (%)	24.89	33.63	23.64	30.98	24.80	33.07
Fixed carbon (%)	29.56	39.95	32.58	42.70	29.85	39.80
Ash (%)	6.88	9.30	8.33	10.92	6.83	9.10
Sulphur (%)	.21	.28	1.53	2.00	.43	.57
B.T.U. per lb.	6,464	8,735	6,750	8,847	6,450	8,600
Color of ash	Light brown		Dark brown		Light brown	

Table 5

Analysis of Turtle Mountain Lignite (from Swartzman, 1953).

Location: Tp. 1, R. 24WPM, near Goodlands (last listed in 1944, with George E. Cain, operator, at Henderson mine).

No. of samples 3

Chemical properties:

Proximate analysis (as received)

Moisture	31.7%
Ash	7.5% (1)
Volatile matter	26.9%
Fixed carbon	33.9%

Ultimate analysis (as received)

Sulphur	0.5%

Calorific value (as received) 6,995 b.t.u./lb. (2)

Caking properties:	
Volatile matter residue-950° C	Non-agglomerate
Caking index (Gray)	0
Swelling properties:	
swelling index (A.S.T.M.)	0
swelling index (F.R.L.)	0
Analyses for classification	
capacity moisture	33.0% [3]
B.T.U./lb. (capacity moisture basis)	6,860
Classification by rank	
A.S.T.M.	Lignite
Specific Volatile Index	79-Border of lignite and peat

(1) Ash: range 7.5 to 12.3%, average 11.0%

(2) Calorific value: Dry-MM free: 11,658 b.t.u./lb. (3 samples)

(3) May be somewhat low

EXPLORATION FOR LIGNITE, 1952 TO 1972

Four separate exploration programs, in which it was hoped to outline lignite reserves suitable for strip mining, were carried out in the Turtle Mountain area in 1952, 1955, 1956 and 1972. The information available in the Non-Confidential Industrial Minerals Assessment Files, Manitoba Mineral Resources Division, is listed in Table 6.

Table 6

Exploration Data in Non-Confidential Industrial Minerals Assessment Files

File No.	
17	Lignite: West Canadian Collieries Limited; 1952. Location: Tp. 1 and 2, rges. 23 and 24WPM. 1 map. Brief logs for 10 drill holes.
18	Lignite: Waskada area, C.F. Doerr; 1955. Location: Tp. 1, rge. 23 to 26WPM; tp. 4, rge. 26WPM. 1 map. 1 report, with lithologic logs of 12 drill holes.
19	Lignite: West Canadian Collieries Limited; 1956. Location: Tps. 1 and 2, rges. 23 and 24WPM. 1 map, with notes on lignite occurrences in margin; 101 holes drilled.
20	Lignite: Luscar Limited, 1972. Location: Tps. 1 and 2, rges. 19 to 24 WPM. 1 location map. Brief logs for 26 drill holes.

Note: These reports are available, at cost of reproduction, from Manitoba Mineral Resources Division, 993 Century Street, Winnipeg, Manitoba, R3H 0W4.

The most detailed results are available for the west slope of Turtle Mountain. For this area, the results of exploration work, together with thicknesses reported from the lignite operations, are shown in Appendix 1, Figures 4 to 15. All elevations of drill holes have been estimated from 1:50000 topographic maps. The results are discussed in a later section on potential resources of lignite.

Elsewhere, on the north slope of Turtle Mountain, a few exploration holes were drilled (Figure 1). Although some thick beds of lignite have been reported in that area by water well drillers, the probably more reliable results of the work by the lignite companies indicated only small quantities of lignite.

On the eastern slope of Turtle Mountain, available information suggests the glacial drift cover is thick, and only a few intersections of lignite have been reported by water well drillers.

OTHER DATA ON LIGNITE OCCURRENCES

Other sources of information on lignite occurrences at Turtle Mountain are:

1) Early geological reports by Selwyn (1893), Dowling (1902), Tovell (1947), and Elson (1947).
2) Seismic shot-hole drilling, California Standard Company, 1951 and 1954.
3) Oil wells drilled through Turtle Mountain.
4) Manitoba Mines Branch core hole program, 1970 and 1971.
5) Recent geological study of the Turtle Mountain area, by J. Bamburak (1973).
6) Water well records, Water Resources Branch.

The information from these sources is listed in Appendix 2.

EVALUATION OF THE LIGNITE RESOURCES OF THE TURTLE MOUNTAIN AREA

Available data on the lignite resources of the Turtle Mountain area have been reviewed in the foregoing sections and in the appendices of this report.

In an attempt to standardize resource estimates, the Department of Energy, Mines and Resources has recommended specific categories and guidelines (Zwartendyk, 1975). The criteria are summarized below, and shown in Figure 3.

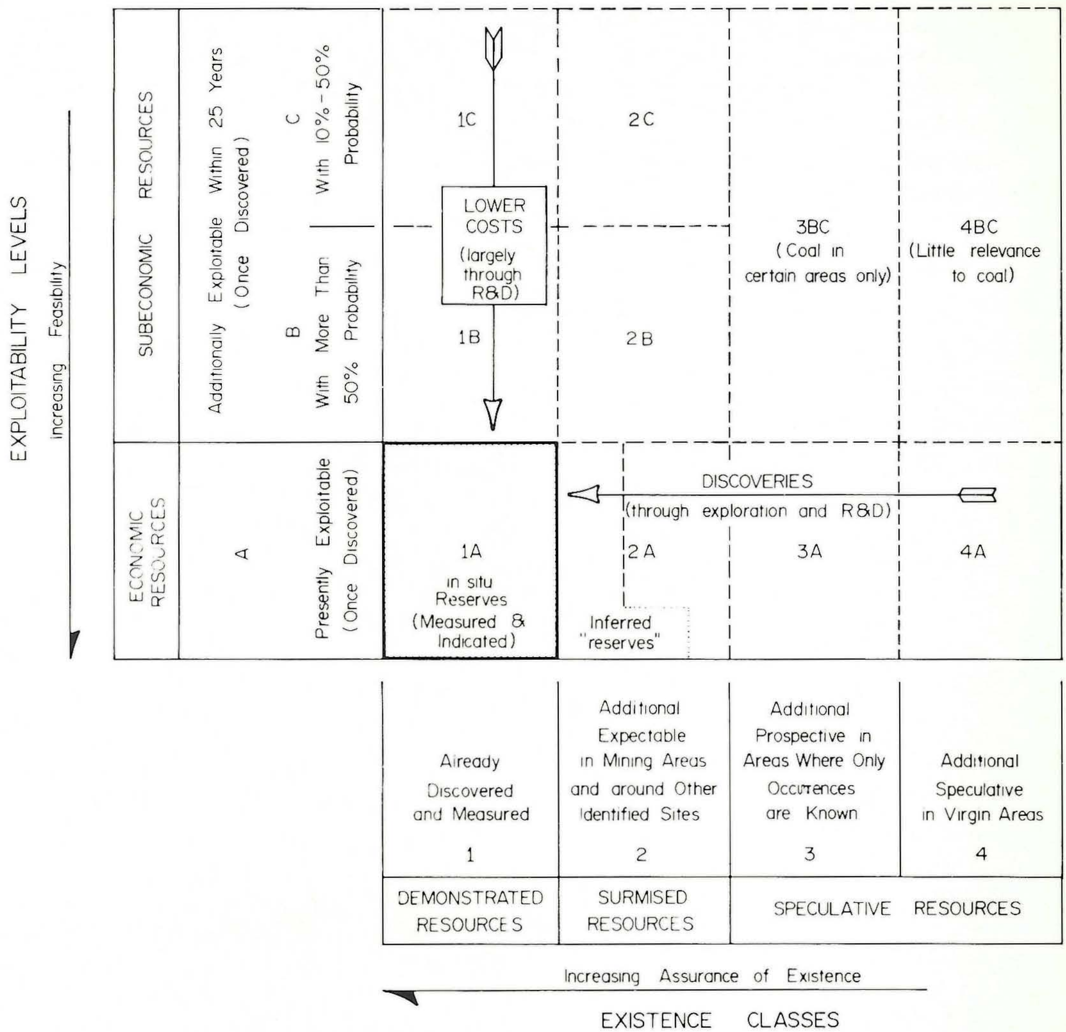
Definitions.

Lignite reserves (1A)

- Lignite deposits are considered "reserves" if they are currently exploitable at a profit.
- In the Plains area, lignite beds should be at least 1.5 m (5 feet) thick and amenable to surface (strip) mining, i.e. generally at a depth of 45 m (150 feet) or less.
- Feasibility of profitable exploitation depends upon prices, mining costs, transportation costs, and available markets.
- For *measured reserves,* points of observation and measurement are so closely spaced — 0.8 km (.5 mile) or less — and the thickness and extent of the lignite so well defined that the error in computed tonnage is judged to be less than 20 per cent.
- For *indicated reserves,* tonnage is calculated partly from measurement, partly from projections for less than 1.6 km (1 mile) on the basis of geological evidence.
- A distinction must be made between *in situ* tonnage and *recoverable net usable* tonnage; (the latter requires completion of exploration work, mine feasibility studies, and open pit design, and must be made before the lignite can be placed in the reserve category).

Lignite resources (1A, 2A, 3A)

- Includes reserves, but also other identified deposits which may be divided into measured, indicated and inferred categories.
- Measured and indicated resources are based on the same criteria as those categories of reserves.
- Inferred resources are based on observation points greater than 1.7 km (one mile) apart, and on a broad knowledge of the geological character of the region.
- Tonnages (2A: surmised, and 3A: speculative) can be estimated only at a low level of confidence, and must necessarily be based largely on expert judgment.



Notes:
1. Coal *reserves* (measured and indicated, i.e. category 1A) should be reported both as in situ tonnage and a corresponding recoverable — net usable — tonnage. All other categories require only in situ tonnage estimates, although rough estimates of recovery factors may be added whenever possible.

   The accuracy of measurement for recoverable reserves needs to be greater than that for in situ reserves or resources, as determination of the recoverability factor requires additional information.

2. For coal, class 3 is of major interest only for special cases, such as the Canadian Arctic. Class 4 has little relevance for coal.

Figure 3. Resource classfication scheme for coal (from Zwartendyk, 1975)

Subeconomic lignite resources (1B, 2B; 1C, 2C)

- Lignite resources that have a probability of greater than 50 per cent of being developed within the next 25 years (1B, 2B) or between 10 and 50 per cent probability (1C, 2C) are included here.
- To determine if the seams are theoretically mineable, provided that the demand exists, requires estimates from mining engineers, transportation specialists, regional planners, and others.
- Seams must be .9 m (3 feet) thick, and less than 457 m (1500 feet) in depth.
- Interpretation of the local conditions may add certain qualifications to the estimates of resources.

Turtle Mountain Area

In attempting to apply the above categories to the lignite in the Turtle Mountain area, several qualifications must be considered.

- The reliability of the data must be evaluated. The results of the exploration by drilling companies are considered reliable within $\pm$ 15 cm ($\pm$ 0.5 feet) for thickness. Some of the thicknesses reported in logs of water wells may be considerably in error (based on results of exploration drilling that tested reported occurrences of thick lignite beds). The only hard evidence is from outcrops, drill core, or measured sections in former mine workings.
- The lignite apparently occurs in lenses of limited horizontal extent, and more than one seam may be present in some areas.
- The above criteria do not provide specifically for evaluation of more than one seam; where the lower or lowest seam is greater than 0.9 m (3 feet) in thickness, it is considered in resource estimates.
- The area along the western slope of Turtle Mountain has been subjected to Pleistocene glaciation, and some evidence exists that ice-thrusting of beds, or possibly slumping, has occurred. (Dips of up to 25° have been reported for what normally should be horizontal beds).
- Quality of the lignite is variable from place to place, based on evidence from former mines. Only a limited amount of data are available, insufficient for a proper evaluation of over-all quality.
- Studies of mining feasibility, mining costs, transportation costs, and potential markets have not been made.

Summary of Lignite Resources

The main lignite seams occur near the base of the Goodlands Member of the Turtle Mountain Formation. The area where these beds can be expected to occur at or near the surface is in a belt, 0.8 to 1.6 km (½ to 1 mile) in width, extending along the lower slope of Turtle Mountain between the 518 m (1700-foot) and 564 m (1850-foot) contours.

An evaluation of resources, using all available data presented in this report, is summarized in Table 7. Tonnages are assigned to various resource classes, based on the criteria proposed by Zwartendyk (1975).

Table 7

Summary of Lignite Resources (in situ)

Area	*Lignite seam*	*Average thickness metres (feet)*	*Short tons*	*Average depth metres (feet)*	*Resource class*
E½ sec. 13-1-24WPM	upper	0.3 (0.9)	450,000	14 (48)	2C
	lower	1.1 (3.7)	1,850,000	14 + 5 = 19 (48 + 17 = 65)	1C
E½ sec. 24-1-24 WPM	upper	variable	500,000	15(50)	2C
	lower	est.1.2 (4.0)	2,000,000	15 + 9 = 24 (50 + 30 = 80)	2C
S½ sec. 25-1-24WPM	upper	0.3 to 0.9 (1 to 3)	1,500,000	6 to 9 (20 to 30)	2C
E½ sec. 25-1-24WPM	lower	0.1 to 2 (0.3 to 6.7)	1,500,000	6 + 24 = 30 (20 + 80 = 100)	3C
S½ Tp. 2, Rge. 23W	main seam	0.6 to 0.75 (2 to 2.5)	1,000,000	?	3C
	McArthur mine, (2 seams combined)	1.2 to 1.5 (4 to 5)	2,000,000	dips to 25°	3C
Tp. 2, Rge. 22W	Preglacial valley		—	—	Nil
Tp. 2, Rge. 21W	Thick lignite seams reported by water well drillers were not confirmed by coal company exploration.				Nil
Tp. 2, Rge. 20W	Logs from two water wells indicated 1.2 m (4 feet) of lignite at a shallow depth; unconfirmed				?
Tp. 2, Rge. 19W	One report of .9 m (3 feet) of lignite at a depth of 9 m (30 feet)				?

A discussion of resources within specific townships is given in Appendix 3.

It should be noted that the results are based mainly on reports submitted to the Mineral Resources Division. Elevations of drill holes were not surveyed, and thus correlations are uncertain. Thickness of lignite seams determined by rotary drilling methods are not always easy to interpret accurately, and thus the results should be considered as being estimated only. Also the lignite seams are lensoid in nature, and some disturbance, either through slumping or by ice-thrusting during Pleistocene glaciation, has occurred in certain areas. For these reasons, the figures for resource estimates listed in Table 7 have a low level of confidence.

The western slope of Turtle Mountain has been adequately explored, but data points are fairly widely scattered on the northern and eastern slopes. Although some exploration potential exists in these areas (exclusive of the areas of known preglacial valleys), the results of exploration drilling to date have been uniformly discouraging. However, a continuous check of any future drilling in the area (e.g. stratigraphic test holes, seismic shot holes, water wells) should be maintained. As discussed in Appendix 3, any lignite present under the upper part of Turtle Mountain is not considered to be economically recoverable; that part of the area is not considered to have any exploration potential.

A note on other occurrences of lignite in Manitoba

Lignite material has been reported from several localities in Manitoba, where it occurs with silica sand and kaolinitic shale of the Upper Cretaceous Swan River Formation. Two of these occurrences — east of Pine River and north of Arborg — have been investigated by companies, but production was not achieved.

The outcrop belt of the Swan River Formation extends along the base of the Manitoba Escarpment from Porcupine Mountain southeastward to Pembina Mountain. Outcrops are rare, occurring mainly along Swan River and Pine River. The formation is exposed also in two quarries south of Ste. Rose du Lac. East of the escarpment, isolated occurrences of Swan River-type material have been intersected in wells, in an area underlain mainly by Paleozoic carbonate rocks. The depths of these occurrences suggest that they are possibly in sink holes or solution channels, as their base level is a few hundred feet (or one to two hundred metres) below the base level of the main area of occurrence of the Swan River Formation.

North of Arborg, carbonaceous material was encountered in 1931 in a well in SE¼ Sec. 22, Tp. 24, Rge. 1 EPM. It was investigated in 1956 by The Winnipeg Supply and Fuel Co. Ltd. and only a small amount of black carbonaceous material was intersected, overlying mixed kaolin, clay, and silica sand; no true lignite was found. Fossil plant material has been identified as of Cretaceous age.

Near Neepawa, Tudale Exploration Ltd. drilled a core hole in 1974 in L.S. 5, Sec. 29, Tp. 14, Rge. 14 WPM. The Swan River Formation was intersected at a depth of 391.7 to 439.3 feet (119.4 to 133.9m). A one-foot or 0.3m interval at 401 feet (122.2m) consists mainly of shiny black lignite fragments that have retained a woody structure, with patches of glauconitic sandstone.

South of Ste. Rose du Lac, the Swan River Formation is exposed in two quarries in Sec. 4, Tp. 23, Rge. 15 WPM, operated by Red River Brick and Tile. Scattered pieces of lignite, some with abundant iron sulphide, were encountered but a continuous bed of lignite is not present.

During a groundwater study at Dauphin in 1970, the Water Resources Branch recovered lignite cuttings from a well in SE¼, Sec. 24, Tp. 24, Rge. 18 WPM, at a reported depth of 135 to 150 feet (46 to 51m). An analysis of the cuttings showed, on a dry basis, 38.6% ash, 27.9% volatile matter, 33.5% fixed carbon, and a heating value of 7400 BTU/lb. Only small amounts of lignite were encountered in surrounding wells in the Swan River Formation.

In the Meadow Portage area, another Water Resources Branch drill hole in 1976 intersected some carbonaceous shale and lignitic material at intervals from 189 to 500 feet (68 to 153m), the total depth of the hole. The depth is notable as the base of the Swan River-type material is at an elevation of 350 feet (107m) ASL, or lower. In the outcrop belt 25 miles (40 km) to the west, the elevation of the base of the formation is 950 feet (290m) ASL.

The Swan River Formation outcrops along Pine River in Sec. 7, Tp. 34, Rge. 20 WPM. An outcrop in the river bank has been described by A.D. Baillie in a brief report (Mineral Resources Division files) as "a seam 3 to 3½ feet thick of coaly material is seen under 4 feet of brownish clay and glacial sand and gravel. Below the coal is a white iron-stained sand". The material was exposed at a depth of 9 feet (2.7m) in two pits, north of the river. Baillie estimated the dip of the seam as 60 degrees at azimuth 30. Some of the lignite contained numerous marcasite concretions. A shaft was sunk in the late 1930's by J. Furber, and the two pits were excavated in 1948 and 1949 by R.W. Johnston, but production of lignite was not attained. Selected samples, reported to be from the shaft, were analyzed. They showed a high ash content (over 25 per cent), and a best calorific value of 4790 BTU/lb. (as received) or 7,760 BTU/lb. (dry basis).

Along Swan River, exposures of the formation show scattered pieces of pyritic lignified wood, similar to the occurrence south of Ste. Rose du Lac.

To date, economic deposits of lignite have not been outlined in the Swan River Formation.

CONCLUSIONS

The following conclusions are derived from the data presented in this report.

1. Lignite seams in the Turtle Mountain area are thin and discontinuous. On the western slope, two seams are possibly persistent, but correlations between individual occurrences are uncertain.
2. Average thickness of the main lignite seam is less than 1.2 m (4 feet). Where greater thicknesses have been encountered, the seam thins laterally within a distance of usually less than 0.3 km (1,000 feet). Discontinuity of the seams may be the result also of faulting, removal by erosion, or glacial disturbance.
3. Recovery of the lignite by underground mining methods is believed unfeasible under current economic conditions. This method would be unsafe because of poor roof conditions and water problems.
4. Previous estimates of tonnage were based on limited data, and were based on the possibility of mining part of the lignite. On the basis of recent exploration data, and considering the areas where lignite is present under less than 24 m (80 feet) of overburden, the probable resources are reduced to a few million tons. By definition, there are no ''reserves'' at Turtle Mountain, because no extensive areas with a 1.5 m (5-foot) thickness of lignite are known.
5. The ratio of overburden thickness to lignite thickness is, for the lowermost slopes of the order of 15:1 to 20:1. This is marginal at best, using current deep-excavation techniques. Limitations set by the amount of overburden that can be removed economically reduce the recoverable tonnage of lignite.

Environmental factors also must be considered. Much of the land in the lignite area is freehold land, and is farm land. Also, any development along the east boundary of tp. 1, rge. 24W (Highway 21) would have high visibility. Strip-mining along the slope of Turtle Mountain may cause drainage problems and increased erosion; excessive gullying due to abundant spring runoff is already a problem in the area.

On the basis of the above conclusions and considerations, further drilling to outline lignite reserves is not considered justified.

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APPENDIX 1

Plan and sections showing results of drilling on western slope of Turtle Mountain

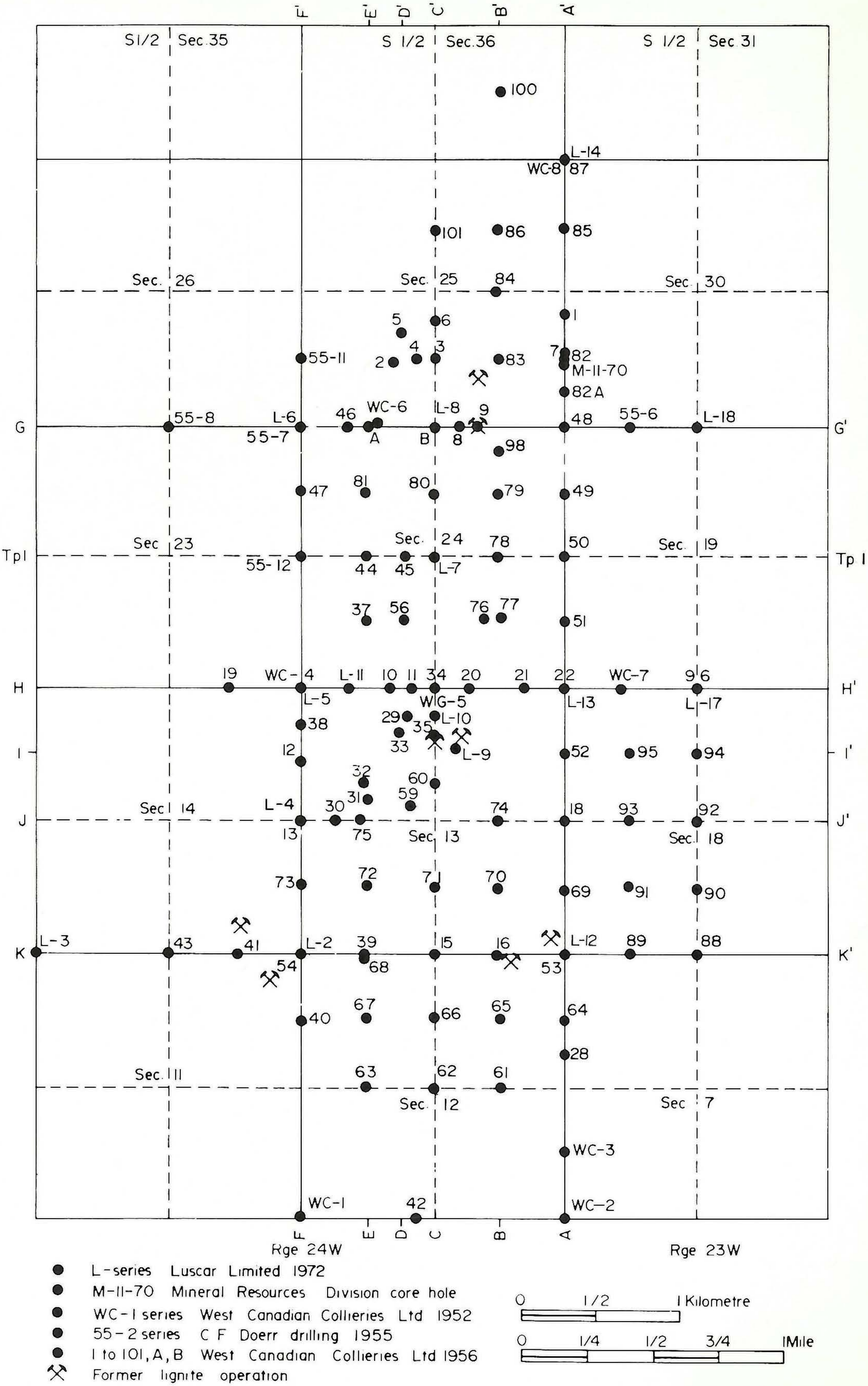

Figure 4. Area of detailed exploration along west slope of Turtle Mountain, showing location of cross-sections A-A' to K-K'.

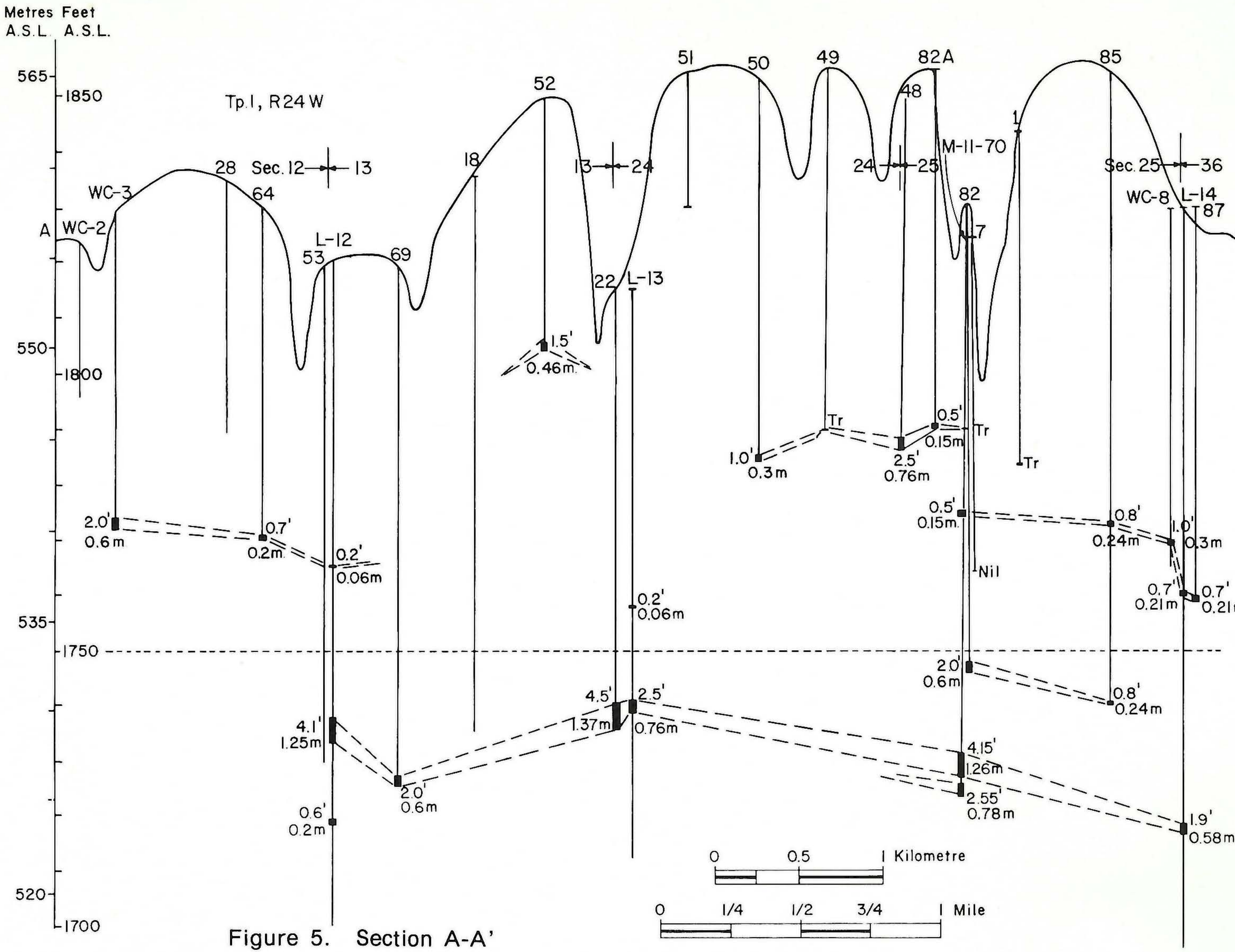

Figure 5. Section A-A'

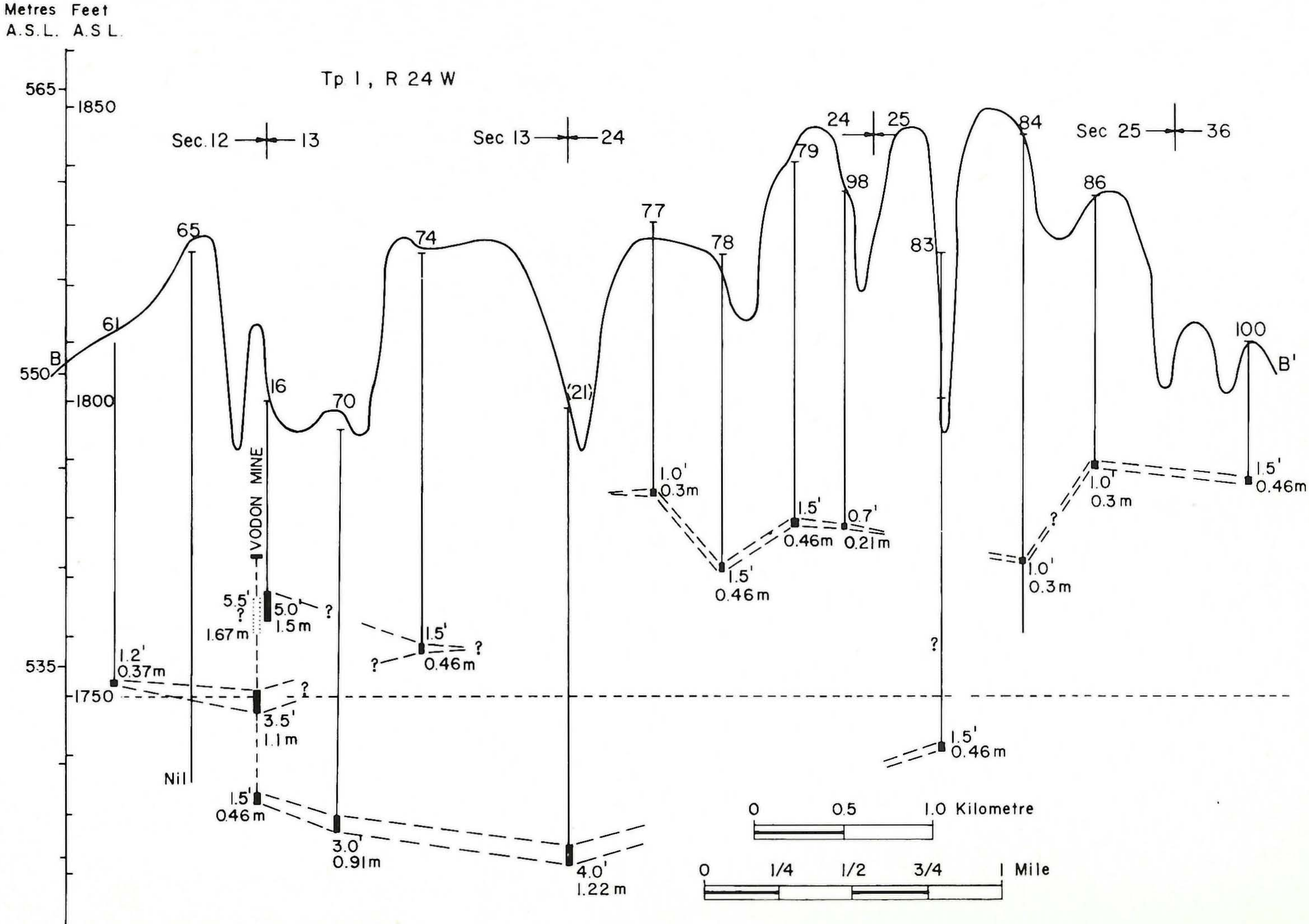

Figure 6. Section B-B'

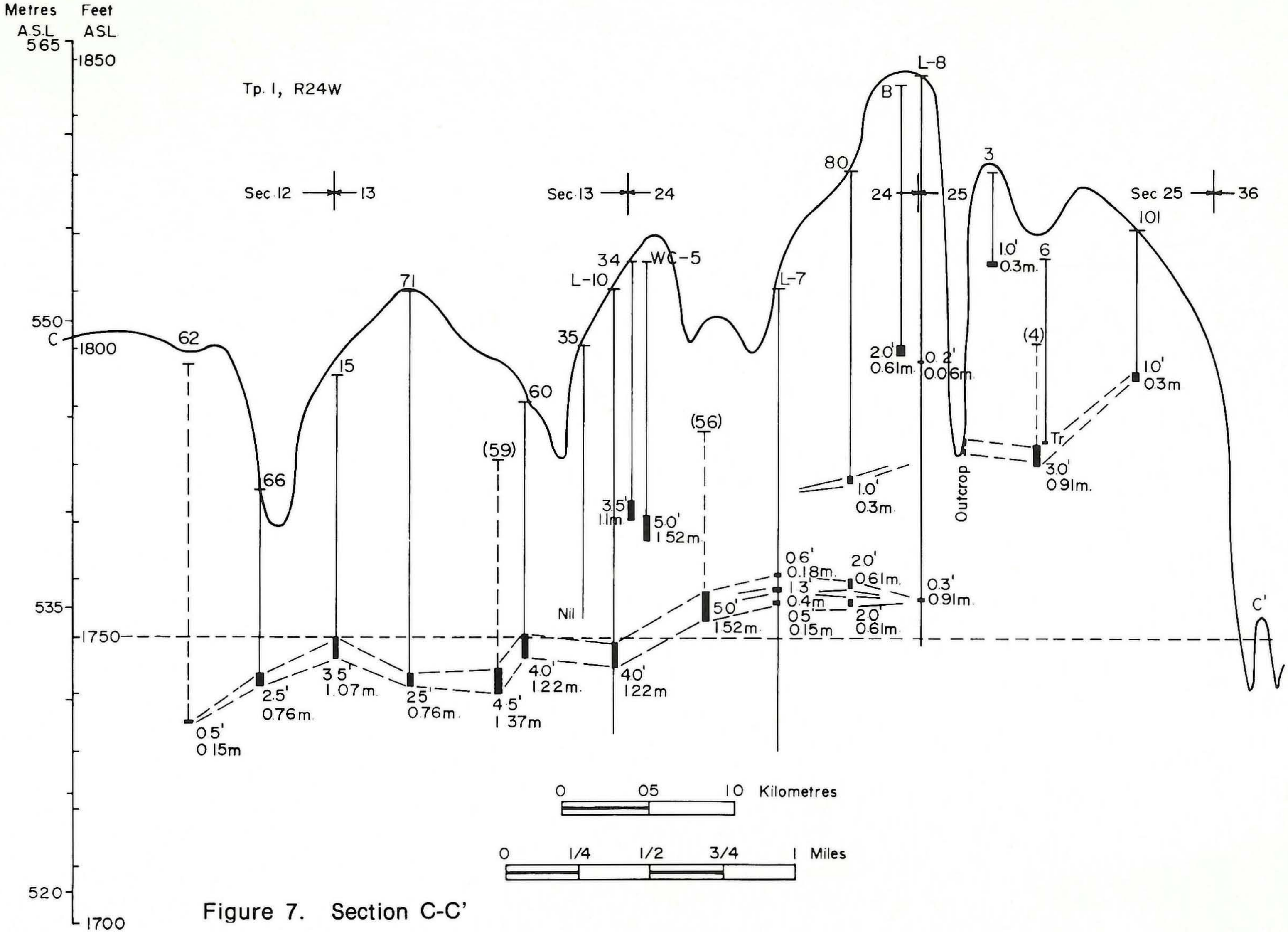

Figure 7. Section C-C'

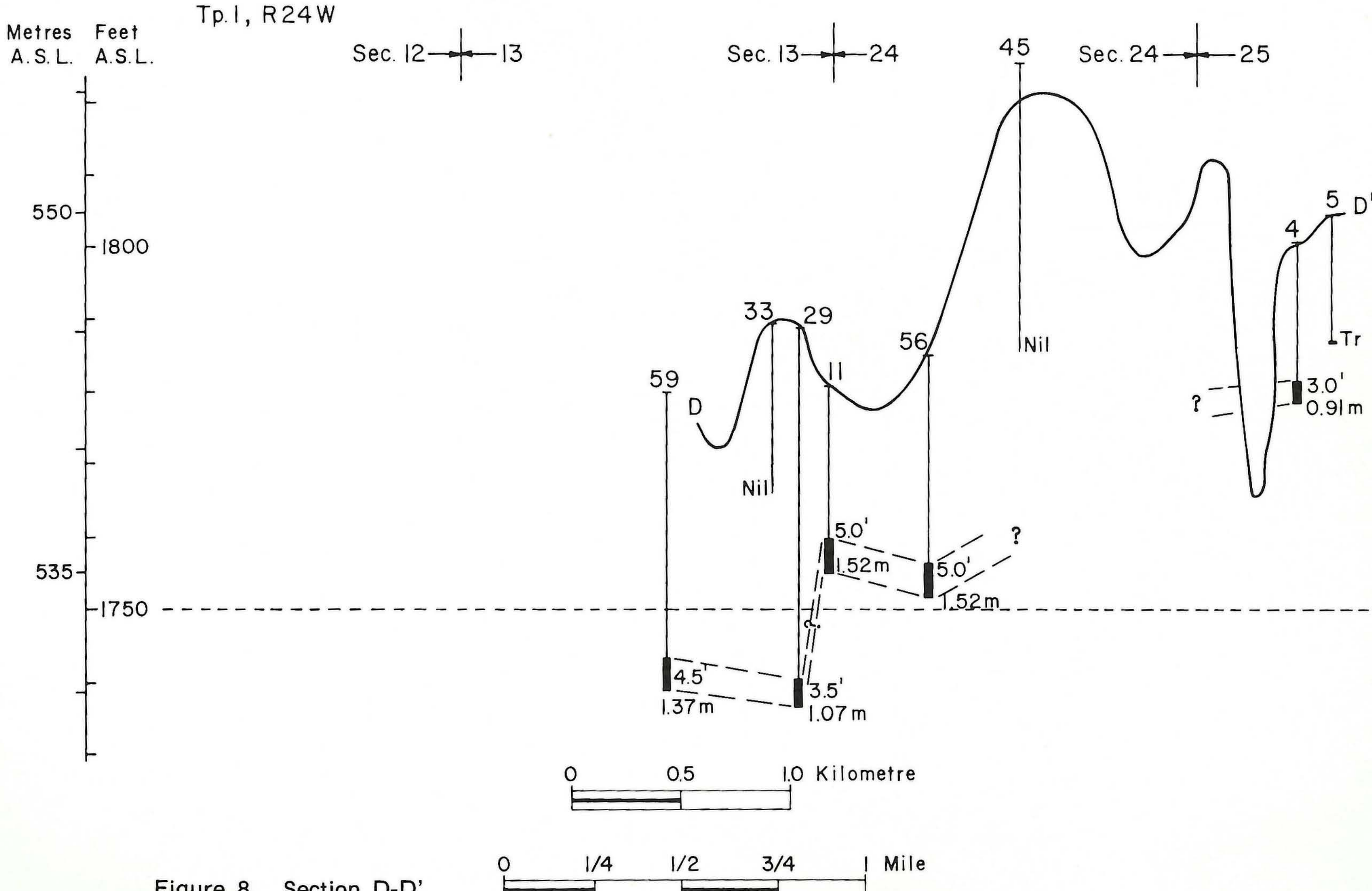

Figure 8. Section D-D'

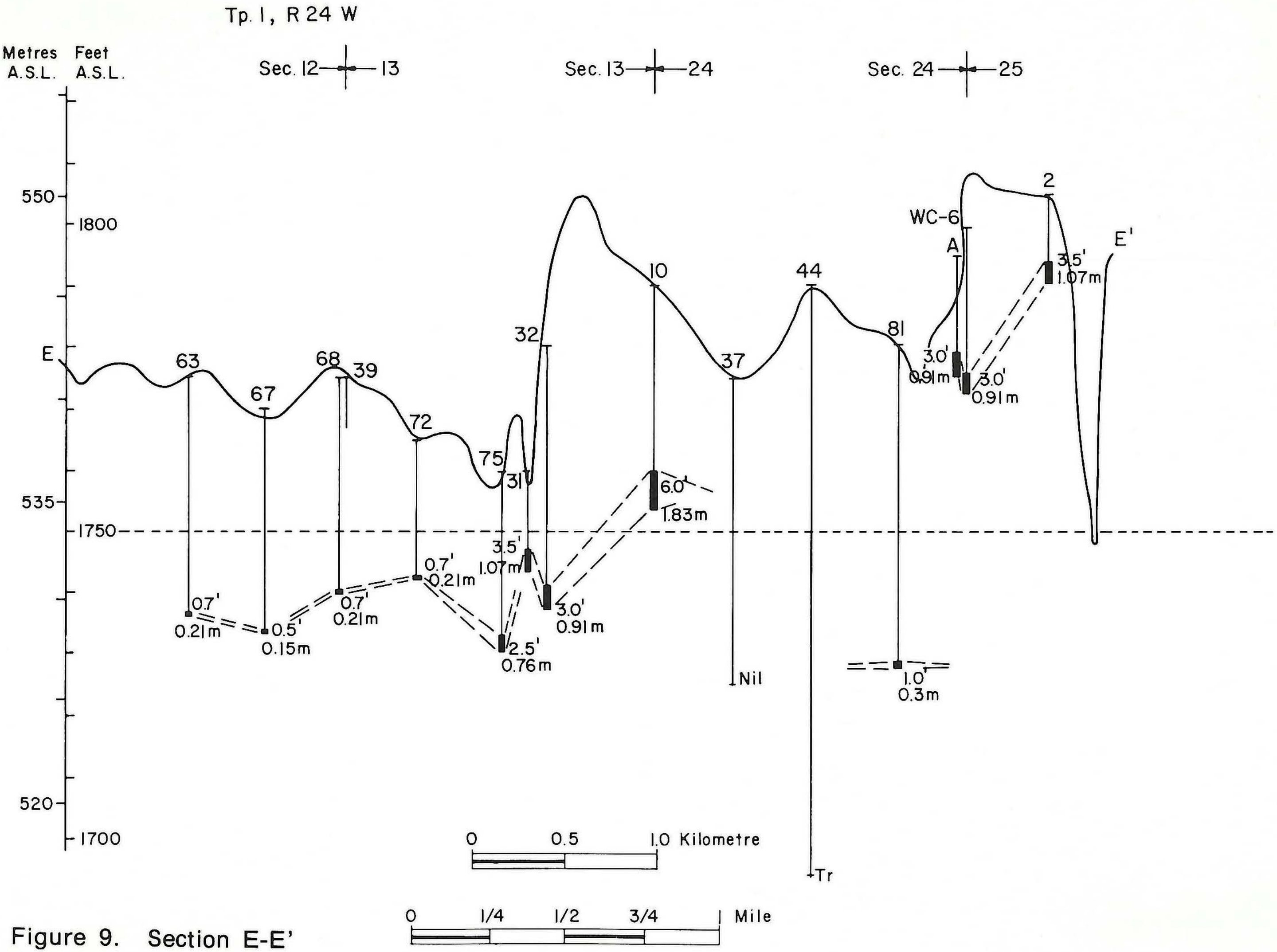

Figure 9. Section E-E'

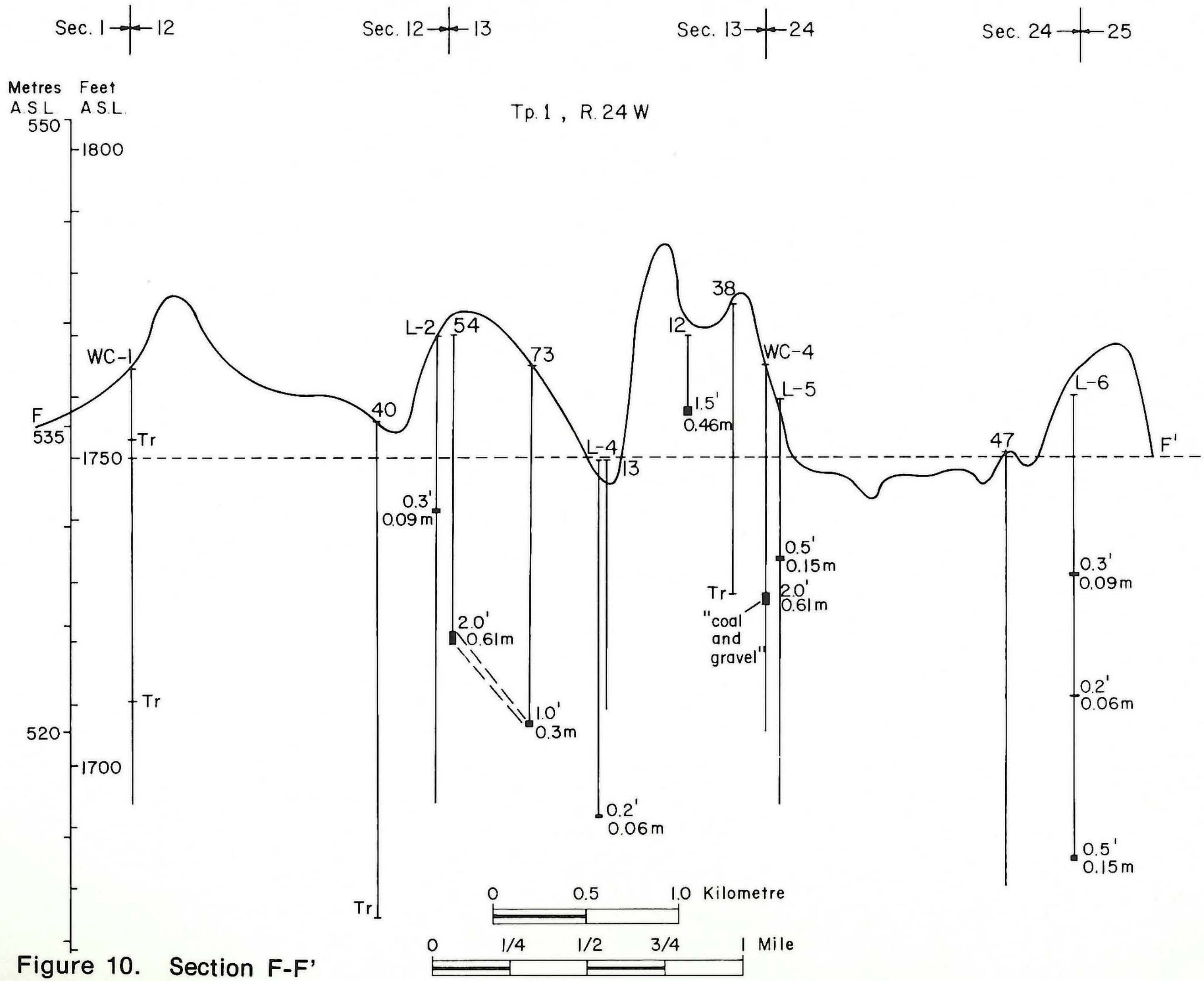

Figure 10. Section F-F'

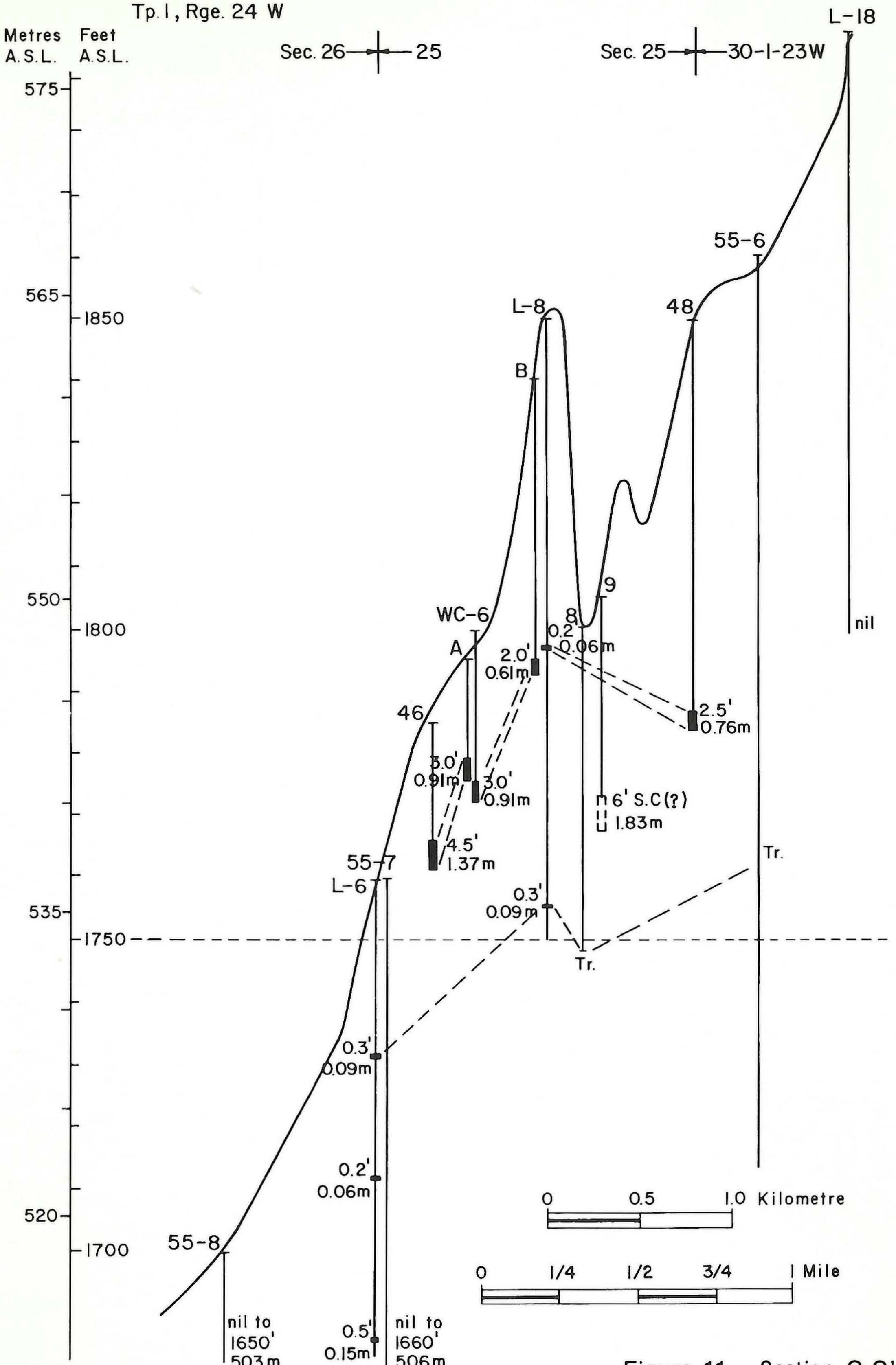

Figure 11. Section G-G'

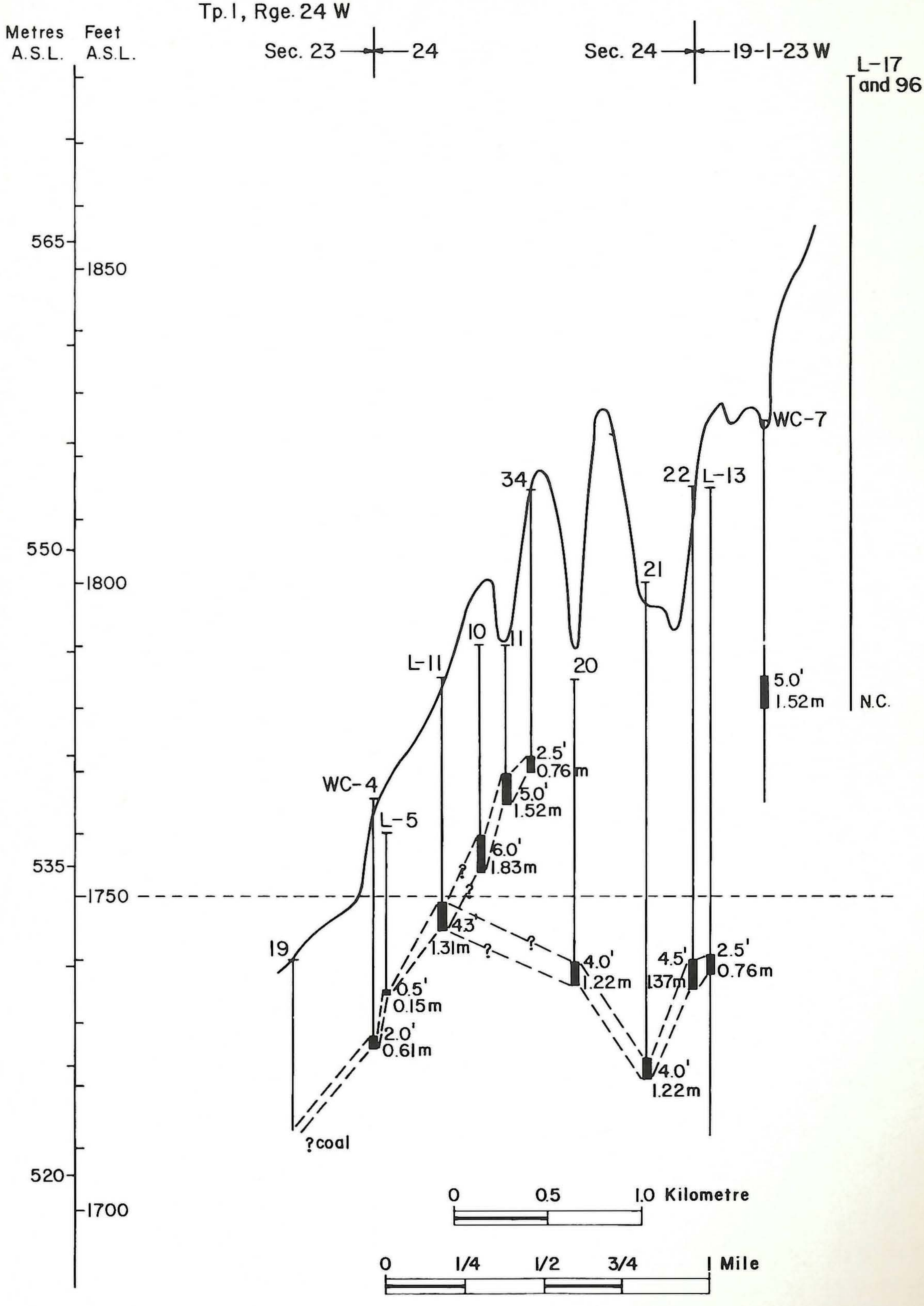

Figure 12. Section H-H'

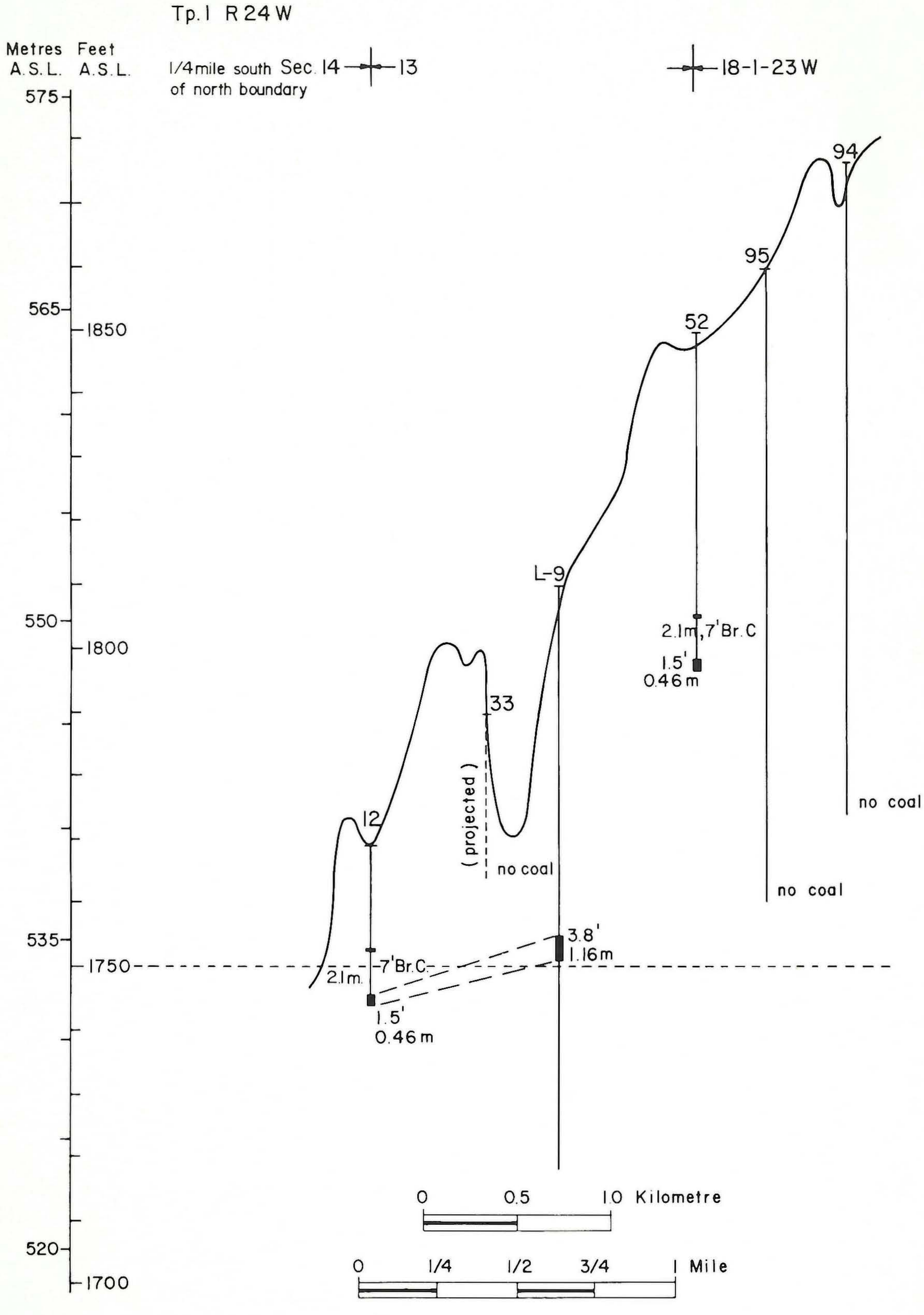

Figure 13. Section I-I'

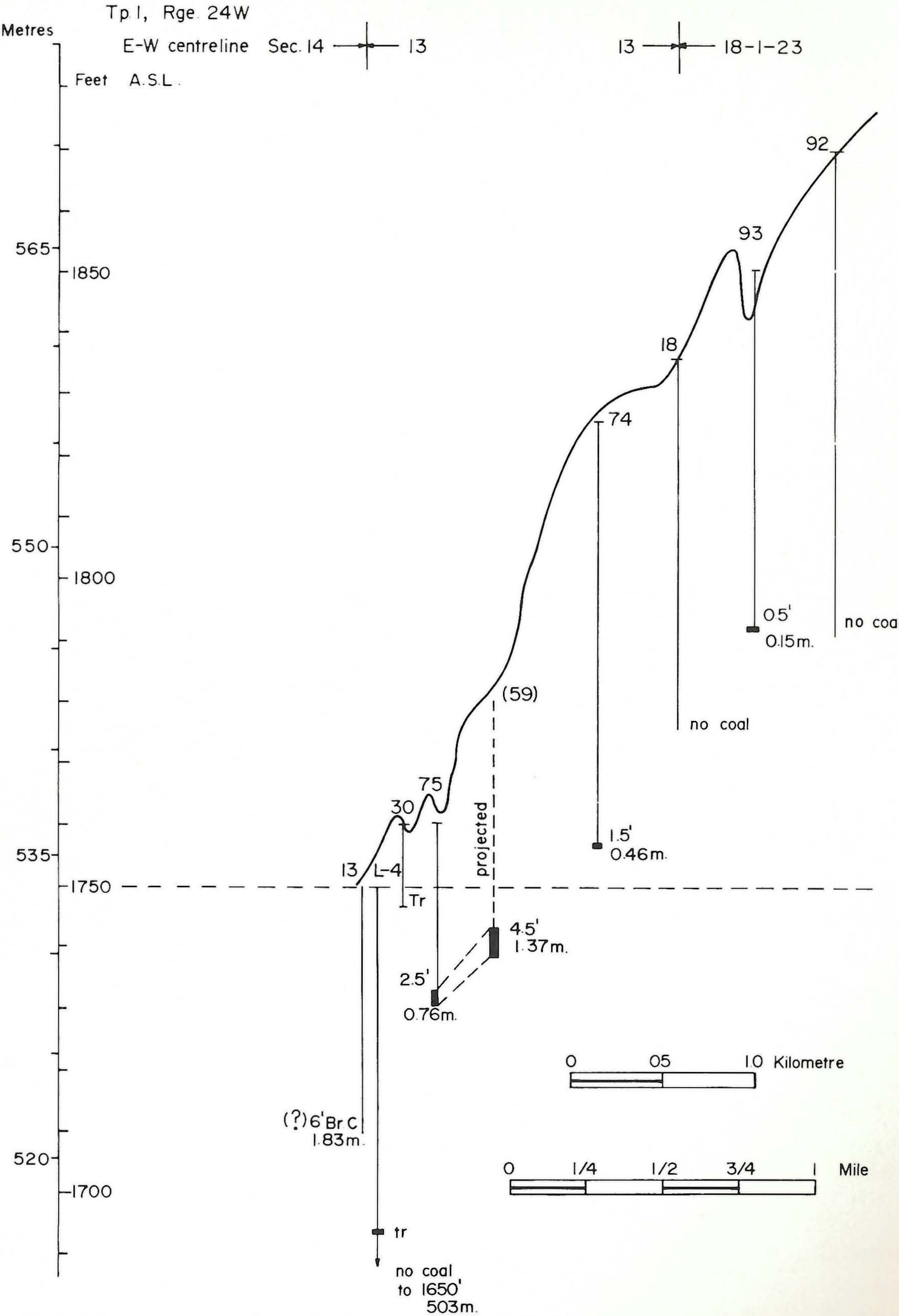

Figure 14. Section J-J'

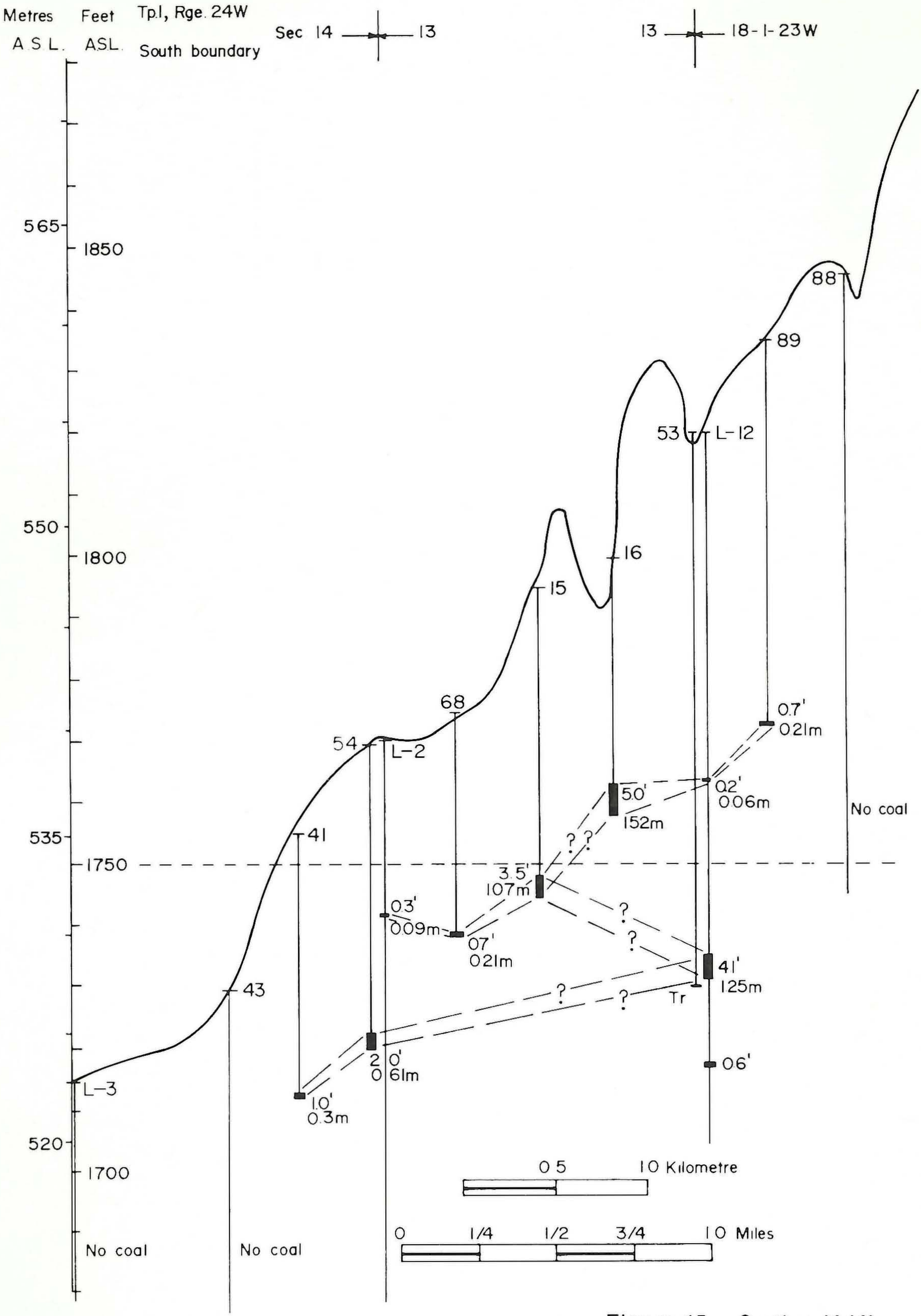

Figure 15. Section K-K'

APPENDIX 2

Data on lignite occurrences
from other sources

Appendix 2

Data on lignite occurrences from other sources

Additional Exploratory Drilling

Table 8

Results of Exploration Drilling Outside the Western Turtle Mountain Area (see Figure 1).

Hole	*Location*	*Elevation Metres*	*Overburden Metres*	*Lignite Metres*	*Elevation Feet*	*Overburden Feet*	*Lignite Feet*
WC-9	SE3-8-2-23WPM	571.5	12	0	1875	40	0
WC-10	SE1-7-2-23WPM	551.7	5.1	0.75	1810	17	2.5
L-15	NE16-31-1-23WPM	617.2	73 +	0	2025	177 +	0
L-16	61m (200 ft.) E of	530.4	10	0.06	1740	32	0.2
	NW13-6-2-23WPM	542.5	13	trace	1780	43	trace
L-19	NW15-8-2-23WPM	542.5	51 +	0	1780	137 +	nil
L-20	SW12-15-2-23WPM	588.2	73 +	0	1930	177 +	nil
L-21	SW12-12-2-23WPM	640.0	45 +	0	2100	150 +	nil
L-22	SW4-2-2-23WPM	657.3	7 +	coal chips	2150	24 +	coal chips
L-23	in SW¼-11-2-22WPM	579.1	17, 22	0.03, 0.15	1900	57, 75	0.1, 0.5
L-24	in SE¼-21-2-21WPM	574.5	23	0.03	1885	77	0.1
L-25	in NW¼-21-2-21WPM	542.5	22, 33	trace, 0.15	1780	75, 110	trace, 0.5
L-26	NE16-29-2-19WPM	570.9	34	0.3	1873	113	1 +
M-2-71	15-5-2-23WPM	600.5	76	0.75	1970	252	2.5
MNR-1	15-32-1-22WPM						

Early Geological Reports

References to lignite in the reports of Selwyn (1893), Dowling (1906), Tovell (1947), and Elson (1947) are listed in Table 9.

Table 9

Lignite Occurrences: From Geological Reports
(Elevations (el.) are at Top of Lignite Seam)

Location	*Reference*	*Lignite occurrence*
Sec. 12-1-24W	Selwyn	1) Vaden mine, in well, under 2.1 m (7') of overburnden: 1.7 m (5.5') ("maybe a mistake"), 1.1 m (3.5') and 0.5 m (1.5') lignite. 2) Vaden mine, shaft 137 m (450') N. of well; 1.4 m (4.5') lignite at 12.2 m (40'), 3.7 m (12') sandy shale, 0.5 m (1.5') lignite; el. of top seam is 535 m (1754').
NW¼-12-1-24W	Dowling	Lignite bed 0.6 m (2') below creek, 45.7 m (150') west of Vaden mine. In pit in north bank (first production: 10 tons), 1.2 m (4') lignite bed from 533.7 m (1751') to 532.5 m (1747'); tilted slightly north.
25-1-24W (Powne)	Dowling	Coal or coaly matter in well at depth of 31 m (102') [533.7 m (1751') el. of coal]. Pit in ravine bottom intersected lignite at el. 534 m (1752'), at depth of 2.4 m (8').
36-1-24	Dowling	Morningstar well: 0.6 m (1' 10'') seam at 535.2 m (1756') el. (depth of 5.5 m [18']). Same seam by Poole's house, in well in NE¼-36.
NW¼-8-2-23W	Selwyn	Upper seam 0.8 m (2.5') at el. 551.1 m (1808') (depth of 7 m [23']); 0.5 m (18'') clay; lower seam 0.76 m (2.5'). Where clay is absent, 1.83 m (6') lignite. Seam dips slightly to north.
SW part 24-2-23W (1½ mi. N & ½ mi. E of McArthur mine)	Dowling	0.9 m (3') lignite at el. 543.5 m (1783') (depth of 7.3 m [24']) in well. Additional digging may have added 1.2 m (4') more lignite.
NE¼-35-2-20W	Dowling	0.08 m (3'') lignite (very poor) at el. 540.1 m (1772') (depth of 3.7 m [12']) in a well.
SW¼-24-2-20W (R. Johnston)	Dowling	Shallow dug well in depression near west boundary; 1.2 m (4') lignite at el. 559.6 m (1836') (depth of 2.4 m [8']).
SE¼-13-2-20W (J. Dalrymple)	Dowling	In well, lignite thinner than in above well, at el. 562.4 m (1845') (depth of 7.6 m [25']).
12-2-20W (Glover)	Dowling	0.6 m (2') lignite at el. 578.5 m (1898') (depth of 4.6 m [15']); then 1.8 m (6') clay, then a second seam, thickness not known.

Table 9 (Cont'd)

Location	*Reference*	*Lignite occurrence*
18-2-17W	Dowling	0.3 m (1') lignite at el. 556 m (1824') (depth of 8.5 m [28']).
31-1-20W (K. Killer)	Dowling	Island in Max Lake; lignite at depth of 8.2 m (27'), thickness not known.
NE¼-13-1-24W	Tovell	1.1 m (3.5') total thickness of 2 seams, at el. 536.1 m (1759'), at depth of 6.1 m (20').
SW¼-25-1-24W	Tovell	1 m (3' 4'') total thickness of 2 seams, at el. 528.5 m (1734'), at depth of 2.4 m (8').
E½-11-2-23W	Tovell	0.9 to 1.5 m (3' to 5') total thickness of 2 seams, at el. 544.7 m (1787'), at depth of ± 12.2 m (40')
SW¼-10-2-23W	Tovell	About 0.6 m (2') lignite, at el. 542.5 m (1780'), of 13.7 m (45').
NW¼-14-2-23W	Tovell	Lignite reported at el. 542.5 m (1780'), at depth of 15.8 m (52'); thickness?
SW¼-24-2-23W	Tovell	0.7 m (2.5') lignite at el. 542.8 m (1781'), at depth of 7.6 m (25').
SE¼-19-2-22W	Tovell	0.6 m (2') lignite, at el. 541 m (1775'), at depth of 3 m (10').
SW¼-23-2-21W	Tovell	About 0.6 m (2') lignite, at el. 570.9 m (1873'), at depth of 9.1 m (30').
SW¼-12-2-20W	Elson	Lignite at el. 571.2 m (1874') at depth of 11 m (36').
NW¼-18-2-19W	Elson	Lignite at el. 543.5 m (1783'), at depth of 20.7 m (68').

Lignite Encountered in Seismic Shot Holes

The California Standard Company encountered a lignite seam in four seismic shot holes drilled in 1951, as reported in a letter of December 20, 1951 (J.D. Allan, Calstan, to J.S. Richards, Director of the Mines Branch):

> ''We wish to report that one of the seismic parties working for this company encountered a coal seam in four holes drilled as seismic shot holes. The coal was estimated to be three feet [0.9 m] thick in each hole and from fifteen to thirty feet [4.6 to 9.1 m] below the surface. A sample of the coal was not obtained. The location of the four holes that penetrated the coal are as follows:

1. 1195' [364.2 m] north of Northeast corner Section 24-1-24WPM
2. 1230' [374.9 m] north of Northeast corner Section 25-1-24WPM
3. 2490' [759 m] north of Northeast corner Section 25-1-24WPM
4. 1500' [457.2 m] south of Northeast corner Section 36-1-24WPM''.

In the final report on this area, ''Report on the area defined by Petroleum and Gas Reservations Nos. 1, 2, 3, 4, 6, and 9 — Southwest Manitoba block'', by M.S. Stanton, 1954, further references were made to lignite:

> ''The only significant occurrence of potentially economic coal seams were reported from the following localities.
>
> Approximately ¼ mile [402.3 m] east of NE corner 23-1-24 (Line 10, S.P. 387, area MF 1) and,
>
> Approximately ½ mile [804.7 m] east of NE 23-1-24 (Line 10, S.P. 386, area MF 1).
>
> A 3' [0.9 m] seam was reported at a depth of 16' [4.9 m] in the former and a 2' [0.6 m] seam at 45' [13.7 m] in the latter. These seams are possibly contiguous, since their structural elevations are nearly the same at the two localities.
>
> A 2' [0.6 m] seam is reported at a depth of 46' [14 m] at a point ¼ mile [402.3 m] west of NE 36-1-24 (line 14, S.P. 607, Area MF 1).
>
> A deep shot hole, drilled ¼ mile [402.3 m] west of NE 36-1-26 (Line 14, S.P. 647, Area MF1), logged coal and fine gravel between 125' - 140' [38.1 - 42.7 m]''.

Oil Wells and Core Holes in the Turtle Mountain Area

Bamburak (1973) listed the oil wells in the Turtle Mountain area, and, where known, the formations that were intersected. His list is reproduced as Table 10 of this report. Wells number 16, 18, 19, 21, 25, and 28 are stratigraphic core holes (core or sidewall samples) discussed next. The remainder are oil wells.

Available data from oil wells, such as gamma-ray logs, resistivity logs, and chip samples, give some indication of lignite occurrences (e.g., chip samples for well 3 contain lignite at 146.3 m (480 feet), el. 527.6 m (1731 feet), and 173.7 m (570 feet), el. 500.2 m (1641 feet); for well 4, at 172.2 m (565 feet), el. 513.3 m (1684 feet); and for well 6 at 137.2 - 140.2 m (450-460 feet), el. 543. - 540.4 m (1783-1773 feet), and at 161.5 m (530 feet), el. 519 m (1703 feet). However, evidence from chip samples alone must be used with caution.

For well 13, the writer collected well-site samples representative of 3 m (10-foot) intervals from the surface to the base of the Boissevain Formation. Small fragments of lignified plant material were noted at 11 separate elevations in this hole, but only one definite seam of lignite with a thickness of about one metre (a few feet) was noted at a depth of 164.6 m (540 feet) (el. 547.4 m [1796 feet]). A thin seam was noted at 142.3 m (467 feet) (el. 569.7 m [1869 feet]). The elevation of the main seam is confirmed by increased resistivity shown on the electric log of well 13.

Wells number 29 to 32 are outside the area of the occurrence of the Turtle Mountain Formation, but were used by Bamburak (1973) to determine regional structure, based on the structural conformation of the upper surface of the Cretaceous Millwood Member.

Table 10a
Oil Wells and Stratigraphic Test Holes, Turtle Mountain
Area (from Bamburak, 1973, p. 96). Numbered Locations are Shown in Figure 1.
MEASUREMENTS IN FEET

								Riding Mountain Formation		
Well No.	*Well Name*	*Location*	*Kelly Bushing*	*Ground Level*	*Turtle Mountain Formation*	*Goodlands Member*	*Boissevain Formation*	*Coulter Member*	*Odanah Member*	*Millwood Member*
1	GREEN HILLS KILLARNEY	13-36-1-18	1837	1828	1739	?	?	?	?	868
2	CLEARY CALSTAN PROV.	6-21-1-19	2154	2144	1743	?	1687	1584	1451	825
3	AMERADA TURTLE MOUNTAIN PROVINCE "M-A"	16-4-1-20	2211	2201	?	?	1661	1551	1401	817
4	DOME CALSTAN LULU LAKE	9-6-1-20	2249	2238	?	?	1648	1553	1385	828
5	HOMESTEAD et al TURTLE MTN. No. 1	10-26-1-20	2247	2236	1890	?	1648	1538	1414	826
6	CITIES SERVICE EAST MAX LAKE NO. 1	14-29-1-20	2233	2223	1893	?	1667	1567	1433	839
7	ROYALITE TRIAD et al LULU LAKE	9-14-1-21	2260	2248	?	?	1673	1554	1393	830
8	ROYALITE TRIAD et al LULU LAKE	14-14-1-21	2288	2277	?	?	1662	1577	1407	833
9	ROYALITE TRIAD et al LULU LAKE No. 3	15-14-1-21	2271	2259	?	?	1670	1567	1401	831
10	ROYALITE TRIAD et al LULU LAKE No. 1	16-14-1-21	2296	2286	1915	?	1657	1568	1410	835
11	NORTHERN NELLIE LAKE	3-17-1-21	2238	2226	?	?	1642	1554	1391	833
12	ROYALITE TRIAD et al LULU LAKE	2-23-1-21	2283	2271	?	?	1668	1560	1407	839
13	GEOG. CHAGOS LULU LAKE	16-23-1-21	2336	2323	1885	1823	1674	1599	1445	850
14	ROYALITE TRIAD LULU LAKE	6-24-1-21	2288	2279	1809	?	1686	1597	1442	866
15	ROYALITE TRIAD et al MAX LAKE No. 1	4-36-1-21	2287	2278	1828	?	1696	1601	1450	856
16	GEOL. SURV. CAN. 68-33	5-20-1-22	—	2310	2185	—	—	—	—	—
17	BAYSEL CALSTAN SHARPE LAKE	3-27-1-22	2183	2170	?	?	1612	1528	1396	803
18	MINES AND NATURAL RESOURCES No. 1	15-32-1-22	—	1970	1967	1854	1702	1602	—	—
19	MANITOBA MINES BRANCH M-3-71	15-32-1-22	—	1968	1964	—	—	—	—	—
20	CLEARY FLOSSIE LAKE	10-12-1-23	2151	2141	?	?	1657	1540	1469	768
21	MANITOBA MINES BRANCH M-11-70	8-25-1-24	—	1820	1820	1781	—	—	—	—

Table 10a (Cont'd)

MEASUREMENTS IN FEET

Well No	Well Name	Location	Kelly Bushing	Ground Level	Turtle Mountain Formation	Goodlands Member	Boissevain Formation	Riding Mountain Formation: Coulter Member	Odanah Member	Millwood Member
22	PLAZA SOUTH GOODLANDS	1-28-1-24	1635	1624	—	—	—	?	?	759
23	CHEVRON MAX LAKE	4-7-2-20	2114	2102	?	?	?	?	1447	870
24	JUMPING POUND-PROSPECT-HIGH CREST et al HORTON	8-15-2-20	1913	1903	—	?	?	?	?	853
25	MANITOBA MINES BRANCH M-1-71	13-33-2-21	—	1768	—	—	1768	—	—	—
26	OWEN No. 1	8-11-2-22	2124	2118	?	?	?	1615	1465	868
27	MIDWEST IMPERIAL LIEGE	2-3-2-23	2129	2118	?	?	1675	1558	1478	808
28	MANITOBA MINES BRANCH M-2-71	15-5-2-23	—	1873	1873	1833	—	?	?	—
29	CALSTAN DELORAINE	10-31-2-23	1646	1634	—	—	?	?	?	815
30	CALSTAN SOUTH NINGA	9-6-3-18	1710	1699	—	—	?	?	?	884
31	BAYSEL CALSTAN BOISSEVAIN	3-20-3-19	1689	1675	—	—	?	?	?	912
32	SAMEDAN HAMAL BOISSEVAIN	10-6-3-20	1765	1744	—	—	?	?	?	935
33	DOME NACO SOUTH WHITEWATER	2-2-3-21	1788	1779	—	—	?	?	?	938

Table 10b
Oil Wells and Stratigraphic Test Holes, Turtle Mountain Area (from Bamburak, 1973, p. 96). Numbered Locations are Shown in Figure 1.

MEASUREMENTS IN METRES

								Riding Mountain Formation		
Well No.	*Well Name*	*Location*	*Kelly Bushing*	*Ground Level*	*Turtle Mountain Formation*	*Goodlands Member*	*Boissevain Formation*	*Coulter Member*	*Odanah Member*	*Millwood Member*
1	GREEN HILLS KILLARNEY	13-36-1-18	559.9	557.2	530.1	?	?	?	?	264.6
2	CLEARY CALSTAN PROV.	6-21-1-19	656.5	653.5	531.3	?	514.2	428.8	442.3	251.5
3	AMERADA TURTLE MOUNTAIN PROVINCE "M-A"	16-4-1-20	673.9	670.9	?	?	506.3	472.7	427.0	249.0
4	DOME CALSTAN LULU LAKE	9-6-1-20	685.5	682.1	?	?	502.3	473.4	422.2	252.4
5	HOMESTEAD et al TURTLE MOUNTAIN No. 1	10-26-1-20	684.9	681.5	576.1	?	502.3	468.8	431.0	251.8
6	CITIES SERVICE EAST MAX LAKE No. 1	14-29-1-20	680.6	677.6	577.0	?	508.1	477.6	436.8	255.7
7	ROYALITE TRIAD et al LULU LAKE	9-14-1-21	688.9	685.2	?	?	509.9	473.7	424.6	254.0
8	ROYALITE TRIAD et al LULU LAKE	14-14-1-21	697.4	694.0	?	?	506.6	480.7	428.9	253.9
9	ROYALITE TRIAD et al LULU LAKE No. 3	15-14-1-21	692.2	688.5	?	?	509.0	477.6	427.0	253.3
10	ROYALITE TRIAD et al LULU LAKE No. 1	16-14-1-21	699.8	696.8	583.7	?	505.1	477.9	429.8	254.5
11	NORTHERN NELLIE LAKE	3-17-1-21	682.1	678.5	?	?	500.5	473.6	424.0	253.9
12	ROYALITE TRIAD et al LULU LAKE	2-23-1-21	695.9	692.2	?	?	508.4	475.5	428.9	255.7
13	GEOG. CHAGOS LULU LAKE	16-23-1-21	712.0	708.1	574.6	555.7	510.2	487.4	440.4	259.1
14	ROYALITE TRIAD LULU LAKE	6-24-1-21	697.4	694.6	551.4	?	513.9	486.8	439.5	264.0
15	ROYALITE TRIAD et al MAX LAKE No. 1	4-36-1-21	697.1	694.3	557.2	?	516.9	488.0	442.0	260.9
16	GEOL. SURV. CAN. 68-33	5-20-1-22	—	704.1	666.0	—	—	—	—	—
17	BAYSEL CALSTAN SHARPE LAKE	3-27-1-22	665.4	661.4	?	?	491.3	465.7	425.5	244.8
18	MINES AND NATURAL RESOURCES No. 1	15-32-1-22	—	600.5	599.5	565.1	518.8	488.3	—	—
19	MANITOBA MINES BRANCH M-3-71	15-32-1-22	—	599.9	598.6	—	—	—	—	—
20	CLEARY FLOSSIE LAKE	10-21-1-23	655.6	652.6	?	?	505.1	469.4	447.8	234.1
21	MANITOBA MINES BRANCH M-11-70	8-25-1-24	—	554.7	554.7	542.3	—	—	—	—

Table 10b (Con'd)

MEASUREMENTS IN METRES

Well No	Well Name	Location	Kelly Bushing	Ground Level	Turtle Mountain Formation	Goodlands Member	Boissevain Formation	Riding Mountain Formation		
								Coulter Member	Odanah Member	Millwood Member
22	PLAZA SOUTH GOODLANDS	1-28-1-24	498.4	495.0	—	—	—	?	?	231.3
23	CHEVRON MAX LAKE	4-7-2-20	644.4	640.7	?	?	?	?	441.1	265.2
24	JUMPING POUND-PROSPECT-HIGH CREST et al HORTON	8-15-2-20	583.1	580.0	—	?	?	?	?	260.0
25	MANITOBA MINES BRANCH M-1-71	13-33-2-21	—	538.9	—	—	538.9	—	—	—
26	OWEN No. 1	8-11-2-22	647.4	645.6	?	?	?	492.3	446.5	264.6
27	MIDWEST IMPERIAL LIEGE	2-3-2-23	648.9	645.6	?	?	510.5	474.9	450.5	246.3
28	MANITOBA MINES BRANCH M-2-71	15-5-2-23	—	570.9	570.9	558.7	—	—	—	—
29	CALSTAN DELORAINE	10-31-2-23	501.7	498.0	—	—	?	?	?	248.4
30	CALSTAN SOUTH NINGA	9-6-3-18	521.2	517.9	—	—	?	?	?	269.4
31	BAYSEL CALSTAN BOISSEVAIN	3-20-3-19	514.8	510.5	—	—	?	?	?	278.0
32	SAMEDAN HAMAL BOISSEVAIN	10-6-3-20	538.0	531.6	—	—	?	?	?	285.0
33	DOME NACO SOUTH WHITEWATER	2-2-3-21	545.0	542.2	—	—	?	?	?	285.9

Core Holes and Sidewall-Sampled Holes

In 1969, the Manitoba Mines Branch, in participation with the Geological Survey of Canada, obtained sidewall samples at approximately .9 m (3-foot) intervals or less, of the Turtle Mountain Formation and the underlying Upper Cretaceous Boissevain Formation. Two holes were drilled (holes 16 and 18, Table 10). In 1970 and 1971, the Manitoba Mines Branch drilled four shallow core holes in the Turtle Mountain area (holes 19, 21, 25, and 28, Table 10), to obtain data for the geological study of the Turtle Mountain area by Bamburak (1973).

Lignite was reported from holes 18, 21, and 28, but was not recorded in holes 16, 19 and 25. In hole 18 (MNR-1; 15-32-1-22W), lignite was recovered in sidewall samples at two levels, at el. 528.8 - 529.1 m (1735-1736 feet), and at 523.3 m (1717 feet). The upper seam is less than .6 m (2 feet) thick, and the lower seam is less than .9 m (3 feet) thick. The lignite seams occur near the base of the Goodlands Member (Bamburak, 1973) of the Turtle Mountain Formation. In hole 21 (M-11-70; 8-25-1-24), 1.26 m (4.15 feet) of lignite was cored beginning at el. 527.7 m (1731.4 feet), and .78 m (2.55 feet) beginning at el. 526.2 m (1726.25 feet). The elevations are remarkably similar to those in hole 18, some 14 miles to the east.

In hole 25 (M-2-71; 15-5-2-23W) lignite fragments in silty shale were encountered at several levels, but the only lignite seam intersected was at el. 536.5 m (1760.25 feet), at least 0.13 m (0.45 feet) thick. As the walls of the hole collapsed at that point, the full thickness of the lignite was not determined.

Geological Study in 1971 of the Turtle Mountain Area by J. Bamburak (1973)

The first comprehensive survey of the bedrock of the Turtle Mountain area was made by J. Bamburak in 1971, following preliminary work on the clays and shales of the area by Bannatyne (1966, 1970).

Bamburak (1973) divided the Turtle Mountain Formation into the Goodlands Member and the overlying Peace Garden Member. The main occurrences of lignite are within the Goodlands Member, generally 4.6 to 9.1 m (15 to 30 feet) above the Boissevain Formation. Cross-sections of the lignite seams along the western slope of Turtle Mountain indicated that two separate seams were present, and considerable structural relief affects their distribution. The data for the sections were obtained from the 1952 to 1956 exploration programs. (The original drill hole elevations were estimated by the companies, and were not surveyed. They have been re-calculated on the basis of recent 1:50,000 topographic maps, and, together with results of the 1972 exploration program, have been discussed previously in the section on "Exploration for lignite, 1952 to 1972").

Bamburak (1973) outlined areas where preglacial valleys cut the northwestern and northeastern slopes of Turtle Mountain. Because of the thick cover of glacial deposits, these areas (the central and northeastern parts of township 2, range 22W, and all of township 2, range 18W) do not have any potential sites for strip mining of lignite (Figure 1).

Water Well Records

The Water Resources Division of the Department of Mines, Resources and Environmental Management maintains records of water wells drilled in the Province. Since 1963, annual reports listing the wells drilled each year have been issued. Those wells in the Turtle Mountain area in which lignite has been reported are listed in Table 11. From the reports submitted by the water well drillers, it would appear that some of these occurrences are of pieces of lignite within glacial deposits. In some wells lignite of great thickness has been recorded in the drill logs, but subsequent exploration has not confirmed the reported thickness (e.g. in SE¼ 21-2-21W, 1968, p. 70, a "coal" seam is reported from 22.3 to 25.9 m [73 to 85 feet]; a hole by Luscar Ltd. in 1972 in the same quarter section intersected 2.5 cm [1 inch] of coal at 17.4 [57 feet], and .15 m [6 inches] of coal at 22.9 m [75 feet]; the interval between was reported as "grey clay and rocks and coal chips", and no further coal was intersected to the total depth of 47.9 m [157 feet]).

Table 11

Lignite Reported in Logs of Water Wells at Turtle Mountain

Ref [WRB]	*Page*	*Location*	*Depth* *metres*	*feet*	*Reported lignite*
(1974)	23A	SE29-1-18W	26.2-27.4	86-90:	hard black coal; other coal in sandstone and clay to 39.6 m (130 feet)
(1973)	53	SE24-2-21W	12.8-13.4	42-44:	coal
(1972)	33	SW29-3-18W	21.6-22.6	71-74:	thin layers of coal in till (drift)
	39	NW28-2-19W	4.0-7.0	13-23:	till, hard shale, and coal:
			7.0-15.5	23-51:	layers of sandstone, brown clay, and of coal
	45	SE21-2-21W	7.0-9.5	23-31:	grey clay till, bits of coal (drift)
	47	NW14-2-23W	16.5-18.9	54-62:	coal and sandstone (above till);
			27.7-29.6	91-97:	grey clay and coal layers
(1971)	17	NE9-1-18W	6.1-8.2	20-27:	yellow till, bits of coal (drift)
	17	SE29-1-28W	21.3-22.2	70-73:	coal;
			22.2-30.8	73-101:	grey till and coal;

Reference	Page	Location	Depth metres	Depth feet	Reported lignite
(1971)	17	SE29-1-28W (cont'd)	30.8-32	101-105:	coal and grey till;
			32-37.2	105-122:	bedrock shale
	23	NE12-3-19W	45.7-48.2-	150-158:	fine sand and layers of coal;
			48.2 56.4	158-185:	grey till;
			56.4-102.1	185-335:	shale (drift coal?)
	30	SE22-1-20W	18.6-19.5	61-64:	clay and coal;
			19.5-67.1	64-220:	till, etc. (drift ?)
	30	SE22-1-20W	14.3-18.3	47.60:	grey gravelly till, shale and coal pebbles (drift ?)
	30	SE22-1-20W	7-8.2	23-27:	coal, clay or silt;
			8.2-9.2	27-302:	till, etc. (drift)
	30	SE25-2-20W	15.8-18.9	52-62:	grey till, bits of coal;
			18.9-24.7	62-81:	same, with sand stringers;
			37.2-43.3	122-142:	sandstone and coal lenses
	34	SE16-3-21W	23.5-24.7	77-81:	grey sand and pieces of coal
(1970)	57	SE14-1-18W	25-26.2	82-86:	soft coal layers;
			26.2-27.4	86-90:	firm green and grey sandstone;
			27.4-32.6	90-107:	clay and coal lenses
	70	NE21-2-21W	17.4-19.5	57-64:	fairly hard lignite (under till)
	76	NW29-2-22W	14.9-16.5	49-54:	grey clay and bits of coal;
			19.8-20.7	65-68:	sandstone and coal lenses
	77	SW32-2-22W	10.4-11.6	34-38:	brown clay and pieces of coal
	81	SE17-2-23W	12.5-13.7	41-45:	coal and grey sand;
			15.5-16.8	51-55:	coal and soft till;
			24.1-27.4	79-90:	sandstone, sand, layers of coal;
			27.4-36.6	90-120:	green sandstone and coal layers
(1969)	56	NE1-3-21W	4.9-6.7	16-22:	grey till and bits of coal;
			6.7-12.8	22-42:	yellow till, coal, and bits of shale;

Table 11 (Cont'd)

Reference	Page	Location	Depth metres	Depth feet	Reported lignite
(1969)	56	NE1-3-21W (cont'd)	12.8-13.4	42-44:	till;
			13.4-22	44-72:	silty grey clay, bits of coal;
			22	72:	Pierre shale
	59	NE21-1-22W	25.6-41.2	84-135:	grey till, sand lenses, bits of coal;
			41.2-46.9	135-154:	till, gravel, sand (drift)
	59	SE34-1-22W	12.8-15.9	42-52:	grey till, coal, and shale;
			15.9-59.1	52-194:	till, etc. (drift)
(1968)	64	SE14-2-20W	9.1-14	30-46:	shale, 4 feet of coal
	70	SE16-2-21W	13.1-43.6	43-143:	grey till, bits of shale and coal;
			43.6-53	143-174:	brown clay, bits of shale, granite, coal, limestone;
			53-57.6	174-189:	grey till, broken shale and coal;
			57.6-60.7	189-199:	coal seam;
			60.7-69.8	199-229:	grey clay and stringers of coal
	70	SE21-2-21W	22.3-25.9	1) 73-85:	coal seam
			17.4-25.6	2) 57-84:	grey till, bits of coal (drift ?)
			13.4-19.5	3) 44-64:	grey till mixed with coal (drift ?)
	71	SE21-2-21W	17.7-27.7	1) 58-91:	coal; 91-93: coal, grey clay, sand
			20.7-21.6	2) 68-71:	medium sand, clay and coal;
			21.6 22.3	71-73:	till (drift ?)
	71	SE9-3-21W	41.1-44.8	135-147:	slick clay, stratified sand, and bits of coal
	72	NW15-3-21W	5.5-14.9	18-49:	till, clay and bits of lignite;
			22.9-24.7	75-81:	sand, broken shale, and bits of, lignite
	72	SE21-3-21W	9.8-12.2	32-40:	sticky shale and bits of coal;
			12.2-18.3	40-60:	sandy grey till, bits of coal;
			18.3-23.8	60-78:	till (drift ?)
(1967)	38	1-20W (International Peace Garden)	39.9-40.8	131-134:	limestone, shale, bits of coal (drift)

Table 11 (Con'd)

Reference	Page	Location	Depth metres	Depth feet	Reported lignite
	38	SW15-2-20W	5.8-16.2	19-53:	clay, bits of coal, shale;
			18-20.4	59-67:	clay, bits of coal;
			20.4-20.7	67-68:	layers of coal and clay;
			20.7-21	68-69:	coal;
			21-21.6	69-71:	clay and coal layers
	38	SW22-2-20W	17.1-19.8	56-65:	soft coal
	38	SW30-2-20W	33.2-36.6	109-120:	fine and medium sand and bits of lignite
(1966)	47	SE24-2-22W	30.2-31.7	99-104:	clayey sand, bits of coal and shale
(1965)	79	2-1-24W	6.7-7	22-23:	coal;
			7-8.2	23-27:	grey sand, coal layers

APPENDIX 3

Discussion of lignite potential
of specific townships

Appendix 3

Discussion of lignite potential of specific townships

The potential for lignite resources is discussed by township, from west to east across Turtle Mountain. Overburden to lignite ratios are reported on the basis of thickness.

Township 1, Range 24 WPM

The township has been intensively explored. Over 115 drill hole locations are shown in Figure 4, north-south cross-sections in Figures 5 to 10, and east-west cross-sections in Figures 11 to 15. The drill results indicate a lower seam (generally 0.6 to 1.4 m [2.0 to 4.5 feet] thick) at 533.4 ± 5 m (1750 ± 15 feet), and an upper thin seam (generally 0.15 to 0.6 m [0.5 to 2.0 feet]) at 544.1 ± 5m (1785 ± 15 feet) (see Sections A-A', B-B', C-C'; Figures 5 to 7). Because the elevations of the drill holes were not surveyed, correlations are uncertain. It is possible several separate lenses are present, and that the lignite has been disturbed by ice-thrusting or slumping. Also, some discrepancies in the thickness of lignite are present in the results reported from holes drilled in approximately the same location.

In section 13, data on lignite are available from three former lignite mines, and from 42 exploration drill holes. For the eastern half of the section, the strata are listed below. If both seams were recoverable, 72.5 million tons of overburden would have to be removed to recover 2.3 million tons of lignite. The overburden ratio averages 14:1, on combined thicknesses.

Section 13-1-24W	Average Thickness	Range	Estimated short tons (in situ)
Overburden	14.4 m (48 ft.)	—	53.6 million
Upper seam	0.27 m (0.9 ft.)	0-1.5 m (0.5 ft.)	450,000
Intervening strata	5.2 m (17 ft.)	—	18.9 million
Lower seam	1.1 m (3.7 ft.)	0.6-1.5 m (2-5 ft.)	1,850,000

In section 24, both lignite seams are present, but only a few holes have been drilled deep enough to intersect the lower seam. The lower seam, which is present as one bed in the southern part of the section, may split into two or three thin beds with a smaller aggregate thickness to the north. The average thickness of overburden over the lower seam decreases from 33.5 (110 ft.) along the eastern boundary to about 16.8 m (55 feet) along the middle of the section. The strata are listed below. In section 24, about 90 million tons of overburden would have to be removed to recover 2.5 million tons of lignite. The overburden ratio is 16:1, if the upper seam is recoverable. An area of less than 40 hectares (100 acres) in l.s. 3 has an overburden ratio of 5:1.

Section 24-1-24W	Average Thickness	Range	Estimated short tons (in situ)
Overburden	15.2 m (50 ft.)	7.6-24.4 m (25-80 ft.)	56 million
Upper seam	variable	variable	500,000
Intervening strata	9.2 m (30 ft.)	7.6-12.2 m (25-40 ft.)	34 million
Lower seam(s)	1.21 m (4 ft.)	0.73-1.52 m (2.4-5ft.)	2,000,000

In section 25, the aggregate thickness of the two beds in the lower seam in hole M-11-70 is 2 m (6.7 feet), but elsewhere the seam is only 0.1 to 0.6 m (0.3 to 1.9 feet) thick. It is too thin and too deep to be economically recoverable. The upper seam is generally thin or absent, except in the southwestern part of the section where it is 0.6 to 1.4 m (2.0 to 4.5 feet) thick. In an area of 40 hectares (100 acres), about 500,000 tons of lignite is present under 10 million tons of overburden. The overburden ratio is about 10:1.

Section 25	Average Thickness	Range	Estimated short tons (in situ)
Overburden (SW¼)	9.2 m (30 ft.)	6.1-13.7 m (20-45 ft.)	10 million
Upper seam (SW¼)	1 m (3.2 ft.)	0-1.4 m (0-4.5 ft.)	500,000
Intervening strata	30.5 m (100 ft.)	-	-
Lower seam	thin, erratic	0.1-2m (0-6.7 ft.)	Not economic

In summary, the main area of lignite in township 1, range 24 west is in the eastern halves of sections 13 and 24. An estimated 5.3 million tons of lignite is present. More than 170 million tons of overburden would have to be removed to recover it. Drill results suggest that the lignite seams are thin or absent both to the north and south of this area. A feasibility study, involving removal costs, markets, and rehabilitation costs would be necessary to place these deposits, the largest outlined to date at Turtle Mountain, in their true economic perspective. The reaction of companies to date is that the relatively small quantity of lignite involved does not warrant exploitation.

Township 1, range 23 WPM

Thin lignite seams have been intersected in a few drill holes in section 18, but in general lignite is absent in the upper 30.5 m (100 feet) of section. In hole WC-7, a 1.52 m (5-foot) seam of lignite was reported at a depth of 12.2 m (40 feet), but adjacent drill holes (section H-H', Figure 12) do not indicate any continuity to the seam.

Township 2, range 23 WPM

In the southern part of this township, available exploration data and data from water wells indicate the presence of a lignite bed 0.6 to 0.76 m (2 to 2.5 feet) in thickness. In the area of the old McArthur mine and the Deloraine Coal Co. mine, two seams of lignite with an aggregate thickness of 1.21 to 1.52 m (4 to 5 feet) were noted. However, in the mine the seams were observed to pitch as much as 25 degrees, suggesting that they have been disturbed by Pleistocene glaciation. Only minimum production was achieved.

Luscar Limited drilled 5 holes in this township in 1972 (locations are shown on Figure 1). Only traces of lignite, or "lignite chips" mixed with other rock, were reported, except for a possible 0.06 m (0.2 feet) of lignite in hole L-16, at a depth of 9.8 m (32 feet). Somewhat similar results have been reported from water wells (Table 11).

On the basis of occurrences listed in Table 9, the area with the most potential is in the vicinity of the old McArthur mine.

Township 2 range 22 WPM

Tovell (1947) reported a 0.6 m (2-foot) seam of lignite at a depth of 3 m (10 feet) in the SE¼ of section 19 (Table 9). Water wells in the township have not intersected any significant lignite seams. Bamburak (1973) indicated that a pre-glacial valley transects this township, eliminating most of it as a potential source of lignite.

Township 2, range 21 WPM

Tovell reported a 0.6 m (2-foot) seam of lignite at a depth of 9.1 m (30 feet) in the SE¼) of section 23 (Table 9). Lignite of considerable thickness has been reported by water well drillers, particularly in the area of section 21 (Table 6). However, two holes drilled in this section by Luscar Limited in 1972 (holes L-24 and L-25; Figure 1) intersected only minor lignite. In hole L-24, 2.54 cm (1 inch) of lignite was intersected at a depth of 17.4 m (57 feet), and 15 cm (6 inches) of lignite at 22.9 m (75 feet). The interval between was reported as "grey clay + rocks + lignite chips". In hole L-26, similar material was reported from 5.5 to 23.5 m (18 to 77 feet), at which depth 2.54 cm (1 inch) of lignite was reported.

The elevations of the Luscar holes are estimated at 579.1 m (1900 feet) and 574.6 m (1885 feet) respectively. The holes were sunk to depths of 47.9 m (157 feet) and 61 m (200 feet), without encountering any significant seams of lignite. The geologist with Luscar Limited, Dr. Batu Dutt, reported (personal communication) that he thought the water well drillers had observed black fluid with scattered lignite chips in the return water during the drilling, and had misinterpreted these as evidence of "solid lignite".

Township 2, range 20 WPM

Dowling (1903) reported several occurrences of lignite intersected in wells along the east side of this township (Table 9). A well in SW¼ of section 24 intersected 1.21 m (4 feet) of lignite at a depth of 2.42 m (8 feet). A water well drilled in SE¼ of section 14 (Table 11, 1968) reportedly intersected 1.21 m (4 feet) of coal. This area was not tested by the coal companies.

Township 2, range 19 WPM

Doerksen (1971) reported that in 1879 a 0.9 m (3-foot) seam of lignite was intersected in a well in section 3 at a depth of 9.1 m (30 feet). This was the first reported occurrence of lignite at Turtle Mountain. Lignite, of unknown thickness, was reported in a water well in the NW¼ of section 28 (Table 11). Hole L-26 (Figure 1), drilled by Luscar Limited at the NE corner of section 29, intersected a trace of lignite at a depth of 22.9 m (75 feet) and 15 cm (6 inches) of lignite at a depth of 33.5 m (110 feet).

East slope of Turtle Mountain

Only scattered occurrences of lignite have been reported from the eastern part of Turtle Mountain (townships 1 and 2, ranges 17 and 18 WPM). Bamburak (1973) reported a preglacial valley cuts across township 2, range 18 WPM, eliminating most of that township as a potential source of lignite. Lignite has been reported in water wells in township 1, range 18 WPM (Table 6). Dowling (1903) reported 0.3 m (1 foot) of lignite at a depth of 8.5 m (28 feet) in township 2, range 17 WPM (this is beyond the limit of the Turtle Mountain Formation as shown on all geological maps of the area, but may represent an outlier or an occurrence of lignite in glacial drift).

On the east side of Turtle Mountain, in township 1, range 17 WPM, glacial overburden is believed to be thick. The Turtle Mountain Formation underlies only a small portion along the western edge of the township.

Upper part of Turtle Mountain (Tp. 1 and S½ Tp. 2, ranges 19 to 23 WPM)

The area comprises the main portion of Turtle Mountain and includes Turtle Mountain Provincial Park and the International Peace Garden. Data on lignite are based on samples recovered from wells drilled for oil and from sidewall samples from test hole MNR-1 (Table 10 and Figure 1).

Chip samples from the oil wells generally indicate the occurrence of one main seam of lignite. Drill hole spacing is too wide to determine whether the lignite occurs as one continuous seam or as two or more lensoid beds. In hole MNR-1, small fragments of lignite disseminated in shale were noted in the sidewall samples from ten separate levels within the Turtle Mountain Formation, but only one bed of lignite was intersected. Its thickness is estimated at more than 0.3 m (1 foot) but less than 0.9 m (3 feet).

As a bed of lignite 0.3 m (1 foot) thick under an area of 2.59 sq. km (1 square mile) contains approximately 1 million tons in situ, the presence of 200 to 400 million tons or so of lignite under the 518 sq. km (200 square miles) area can be postulated. However, as the seam is less than 1.52 m (5 feet) thick, and as overburden ranges from 45.7 to 152 m (150 to 500 feet), tonnage of lignite cannot be considered as reserves under the criteria specified by Zwartendyk (1975) (see this report, page 15). The lignite may possibly be placed in the subeconomic resource class (seams 0.9 m [3 feet] thick and less than 457 m [1500 feet] in depth), but only on the basis of applying these theoretical considerations. The lignite is considered by the writer not to be economically recoverable at present, and the probability of its development in the next 25 years is considered to be less than 10 per cent.