Report 74-5

SUSCEPTIBILITY OF GEOLOGIC DEPOSITS TO EROSION IN THE HOUSE MOUNTAIN AREA, ALBERTA

C. P. Kathol and R. A. McPherson

Alberta RESEARCH

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SUSCEPTIBILITY OF GEOLOGIC DEPOSITS TO EROSION IN THE HOUSE MOUNTAIN AREA, ALBERTA

Abstract

Oil and gas exploration and development in the House Mountain and Swan Hills areas of Alberta has contributed to extensive erosion of the geologic deposits.

Many factors, such as geologic materials, slope, vegetative cover, soil type, groundwater conditions, time, and climate, affect the processes of erosion.

Air-photograph interpretations and field investigations were utilized in mapping the surficial deposits and assessing their susceptibility to erosion. The erosion susceptibility rating of the materials (from least erodible to most erodible) is as follows: muskeg, gravel, coarse sand, till, clay, shale, fine sand, silt, and sandstone.

The map of surficial deposits and their erosion susceptibilty rating may be used as an aid in formulating land use plans for the area; however, on-site inspections are recommended wherever development occurs in order to assess the erosion hazards of that particular site.

Methods that can be used to prevent or control erosion include:

(1) cutting slopes to as low an angle as possible and disturbing as little surface area as possible;
(2) avoiding areas of highly erodible material where possible;
(3) leaving protective root and topsoil cover on the ground during logging operations and seismic activities;
(4) spreading a layer of roots and topsoil cover on exposed slopes;

(5) laying trees, preferably conifers with numerous branches, on exposed slopes to minimize gullying;

(6) constructing gravel or boulder berms at regular intervals in ditches or on slopes;

(7) avoiding practices which alter the base level of erosion;

(8) avoiding terracing of shale and mudstone slopes which results in increased erosion.

If these techniques for prevention or control of erosion are applied in the early stages of any development, erosion problems will be minimized.

It is important that the type of geologic material at each site be recognized as well as the interrelated factors affecting erosion, so that suitable measures can be taken to prevent or inhibit erosion.

Further studies are warranted to provide specific data on the engineering properties, physical properties, and chemical composition of the geologic deposits. This information would be of considerable value in assessing further the factors affecting erosion in the area.

INTRODUCTION

In 1972, Alberta Environment initiated a study to investigate erosion problems related to oil and gas exploration and development in the Swan Hills area of Alberta. At the request of Alberta Environment, Alberta Research[1] undertook mapping of the surficial geology of the House Mountain area and the establishment of the susceptibility of the geologic deposits to erosion. This report summarizes the results of the survey in the House Mountain area.

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[1] Formerly Research Council of Alberta

The project was coordinated by Dr. R. Green, Chief, Earth Sciences Branch, Alberta Research. Dr. D. A. St.-Onge and Dr. J. Lengellé, who had previously worked in the area for the Geological Survey of Canada, conducted additional field surveys in 1973 and constructed "erosion hazard maps" for map sheets 83J 13 W and E, 83J 14 W and E, and 83J 15 W.

LOCATION AND ACCESS

The House Mountain area (part of NTS 83O) is located approximately 135 miles northwest of Edmonton, Alberta. The area encompasses townships 70 and 71, ranges 9 to 12, and portions of township 69, ranges 9 to 12, W. 5th Mer.

The Town of Swan Hills is approximately 21 miles south of the southern boundary of the study area. A road from Swan Hills to Kinuso traverses the eastern portion of the map area in a north-south direction and parallels the Swan River. Numerous other roads and trails exist throughout the area; however, many are impassible because of washed-out sections.

METHOD OF INVESTIGATION

Prior to field investigations, a preliminary air-photograph interpretation of the surficial geologic deposits was made, on a scale of 1:50,000, to provide a basis for the field mapping.

C. P. Kathol spent several days in the Swan Hills area with Drs. St.-Onge and Lengellé to gain an insight into erosion problems in the area. Based on field observations in the Swan Hills, it was possible to formulate general guidelines for conducting a survey of erosion hazards in the House Mountain area.

Most of the field investigations were conducted by helicopter; flight lines were made on a north-south grid pattern and ground observations were made wherever landing spots were available. The density of ground checks in the northern portion of the study area was not as high as was desired because of a lack of landing sites. Additional information was obtained from road traverses wherever possible. At each observation point, data was collected on the type of geologic deposits, the degree of erosion, the slope of eroded surfaces (utilizing a Brunton compass), and the nature of the vegetative cover. Many observation points were areas that had been cleared for oil and gas exploration and development, such as seismic lines, well sites, battery installations, and lease roads. Therefore, it was possible to assess the erodibility of the various deposits on a range of slopes where vegetation had been removed. It was also possible to determine the degree to which the various deposits would revegetate naturally on different slopes.

Data from the field mapping were used, in conjunction with air-photograph interpretations, to prepare a surficial geology map of the area on a scale of 1:50,000.

In addition, an erosion susceptibility classification for the various deposits was constructed which incorporates the erosion characteristics of the materials for different slopes and their natural revegetation rates.

Recommendations on methods which may be used to inhibit erosion in the study area were also made.

GENERAL GEOLOGY

Bedrock Geology

Most of the area is underlain by Upper Cretaceous rocks of the Wapiti Formation (Fig. 1). The rocks are nonmarine, consisting of grey, feldspathic, clayey sandstones and grey bentonitic mudstone, bentonite, and scattered coal beds (Green, 1972). These rocks are generally overlain by a mantle of glacial and postglacial deposits, and are exposed only on steep slopes and stream valleys.

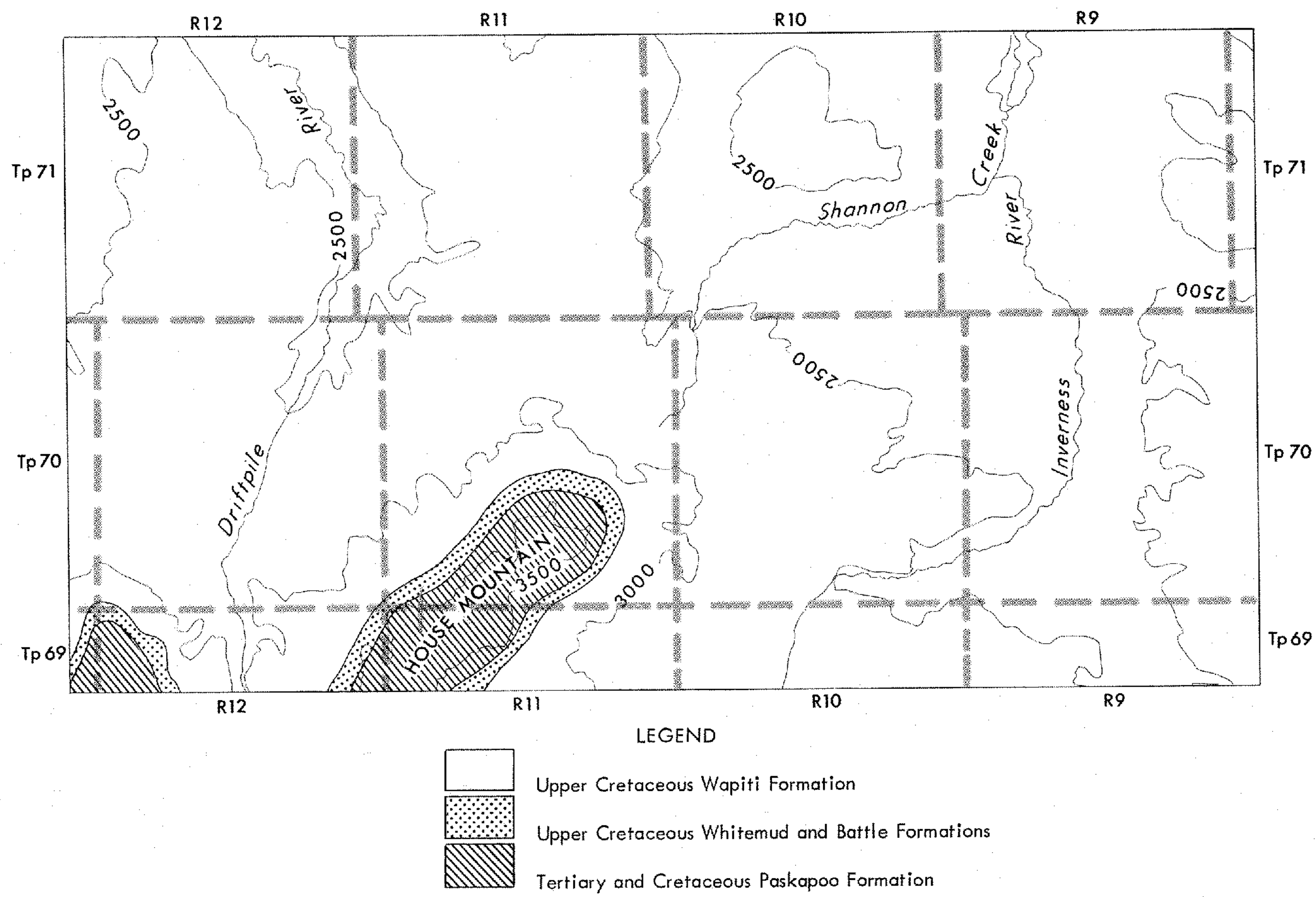

FIGURE 1. Bedrock geology.

In the southwest portion of the study area two major bedrock highs exist which are extensions of the Swan Hills; the larger is called House Mountain (Fig. 1). Around the lower edges of these uplands, the Upper Cretaceous Whitemud and Battle Formations are exposed on steep slopes. The Whitemud Formation consists of pale grey, white weathering, bentonitic sandstone and mudstone. The Battle Formation, which is nonmarine, is composed of purplish black, mauve weathering, bentonitic mudstone containing siliceous tuff beds (Green, 1972).

The rocks overlying the Whitemud and Battle Formations on these uplands belong to the Paskapoo Formation which is Paleocene and Upper Cretaceous in age (Fig. 1). The Paskapoo Formation includes grey to greenish grey, thick bedded, calcareous, cherty sandstone; and grey and green siltstone and mudstone, with minor conglomerate, thin limestone, coal, and tuff beds (Green, 1972). Numerous exposures of the Paskapoo Formation are present, especially on steep slopes on the flanks of House Mountain.

Surficial Geology

The extent and distribution of surficial geologic deposits is indicated on figure 2 on a scale of 1:50,000. A brief description of these materials is as follows:

Alluvial Deposits and Features

Muskeg is present in scattered localities thoughout the area; however, it is most common in the western portion of the map area. The depth of the muskeg deposits is unknown; however, it is greater than 3 feet thick in certain localities since holes dug to that depth did not reach the underlying material.

Stream alluvium has been mapped as a separate map unit along several of the larger streams.

The major stream in the area is the Swan River, flowing from south to north in the eastern part of the map area in a well defined channel. Its valley ranges between 3/4 and 1-1/2 miles in width and is relatively flat bottomed. Alluvial deposits of coarse sand and gravel are common along the valley as are silt and clay (Fig. 2): variations in the lithology of the deposits are too great over short distances to show as separate map units. Higher level terraces are not common along the valley walls. In scattered localities, erosional remnants of glacial deposits or bedrock protrude above the valley floor. Exposures of glacial and bedrock deposits are present along the steep valley walls and are often overlain by a discontinuous veneer of colluvium.

Major tributaries of the Swan River include the Inverness River, Boulder Creek, Shannon Creek, Island Creek, and Adams Creek. All of these streams are characterized by valleys with relatively flat bottoms and steep valley walls. The alluvium consists of coarse sand and gravel, silt, and clay. High level terraces are uncommon on any of these streams.

The other major stream in the study area is the Driftpile River flowing from south to north through the western part of the map area (Fig. 2). The morphology of its valley is similar to that of the Swan River in that it is characterized by steep valley walls and a relatively wide (1/4 to 3/4 mile), flat valley bottom. Alluvium deposited by the Driftpile River consists of coarse sand and gravel, silt, and clay (Fig. 2). High level terraces are poorly developed.

Numerous small tributary streams enter the Driftpile River in the map area.

Recent lake and slough deposits occur in isolated localities in the study area. The sediments consist of thin layers of silt, clay, organic muck, and marl (Fig. 2). Deposits of this type can be expected in many of the small depressions in the map area; however, field data is not sufficient to delineate them in detail or they are too small to show on a 1:50,000 map.

Glaciolacustrine Deposits

Glaciolacustrine silt and clay is present in the northwest part of the map area (Fig. 2). The sediments are characterized by rhythmically bedded silt and clay containing lenses of pebbles and till-like material interpreted to have been deposited by ice rafting or mud flow, or both. The topography in these areas is flat to gently undulating.

Glaciolacustrine silt is present along the margins of the Swan River valley as shown in figure 2. In places these deposits have a relatively flat upper surface and in others the surface topography is gently undulating to hummocky. The sediments are composed primarily of silt with occasional till-like lenses and clay layers, and vary in thickness from a few feet to over fifty feet.

Glacial Deposits

Hummocky dead ice moraine is common in the southern part of the study area. The main topographic expression of the hummocky moraine is a complex of knobs and kettles. The knobs and hills are circular to oval in plan outline and range from a few feet to greater than 200 feet in diameter and from a few feet to greater than 60 feet in height. The kettles are small closed depressions generally less than 15 feet deep.

The dead ice moraine is composed primarily of till, consisting of unsorted clay, silt, sand, and gravel with pebbles and boulders. Bedrock fragments and lenses of sand and gravel are common in the till. A small percentage of the hummocks are likely composed of silt and clay or sand and gravel as is generally the case with hummocky moraine.

Ground moraine, defined as a level to gently undulating till plain, is the most extensive surficial deposit in the House Mountain area (Fig. 2). The till is unsorted, unstratified sediment deposited by a glacier and consists of a mixture of silt, clay, sand, gravel, and boulders. In general, the till contains a relatively high percentage of silt and clay; however, on major topographic highs the tills are often quite stoney and in some instances resemble a poorly sorted gravel.

Thin till over bedrock. In portions of the area, a discontinuous veneer of till (generally less than 10 to 15 feet thick) overlies the bedrock. The till is similar to that found in the ground moraine but because bedrock is at or near surface in many localities, a separate map unit has been used to describe these areas. Thin till over bedrock is generally found on slopes near the top of large bedrock uplands (Fig. 2).

Bedrock plateaus occur as flat-topped erosional remnants on House Mountain above 3,750 feet. The tops of these remnants are relatively flat, except where they have been gullied by surface water runoff. A thin veneer of sand, silt, and clay, interpreted to be primarily weathered bedrock, overlies bedrock of the Paskapoo Formation. No quartzite gravels were found on House Mountain although they are present in the Swan Hills on similar bedrock highs to the south (St.-Onge and Richard, 1967).

Erosional Features

Gullies, creek valleys, and scarps are common in the study area. Larger features of this type are shown on figure 2. They are characterized by steep slopes along which exposures of bedrock or glacial deposits often have a discontinuous veneer of colluvium. The small creek bottoms contain thin alluvial deposits of silt, clay, sand, and gravel.

Eroded bedrock has been mapped as a separate unit on the flanks of House Mountain (Fig. 2). This area is characterized by highly dissected bedrock deposits and steep slopes with little or no vegetative cover. Small patches of glacial till are present in areas that have escaped erosion.

Eroded hummocky moraine has all the characteristics of hummocky moraine; however, because it was deposited on relatively steep bedrock slopes, it has been highly dissected by gullies and small streams. Because the channels are too small and complex to show on a 1:50,000 map, these deposits are outlined as separate map units to distinguish them from normal hummocky moraine

Similarly, *eroded ground moraine* has all the characteristics of ground moraine except that it also has been eroded and dissected by numerous gullies and streams. A separate map symbol has been used to distinguish these areas from normal ground moraine.

SUSCEPTIBILITY OF GEOLOGIC DEPOSITS TO EROSION

Factors Influencing the Erodibility of Geologic Deposits

Many interrelated factors affect the susceptibility of geologic deposits to erosion. Some of the more important factors include geologic materials, slope, vegetative cover, soil type, groundwater, time, and climate. A brief description of the possible effects these factors have on the erodibility of geologic deposits in the House Mountain area is as follows.

Geologic Materials

The grain size of the sediments controls the degree to which surface water will percolate into the deposits and become part of the groundwater system. For example, fine-grained deposits generally inhibit percolation and result in higher surface water runoff which may form gullies. Furthermore, finer particles may be carried downslope more readily by surface water. Cementation of the geologic materials affects the permeability and hence the erodibility of the deposits.

The composition and grain size of the materials is important because it controls the nature and rate of soil-forming processes.

The geotechnical properties of the geologic materials which affect slope stability, susceptibility to frost heave, and so on (processes contributing to erosion), are dependent on both the grain size and composition of the materials.

Slope

In general, the steeper the slope, the more susceptible the geologic deposits are to erosion.

Vegetative Cover

In general, the denser the vegetative cover, the more resistant the deposits are to erosion.

Soil Type

The soil type is important because it is related to the nature of the vegetative cover. Soils consist of variable mixtures of weathered rocks and minerals, organic matter, water, and air. They are the products of the environmental conditions under which they have developed and their characteristics are dependent upon climate and vegetation, nature of the parent material, relief and drainage, biological activity, and the length of time that these forces have been in operation.

It has been demonstrated that 13 essential elements are required from mineral soils to support plant life (Buckman and Brady, 1960). Six elements which are used in relatively large amounts (macronutrients) are nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur.

Factors affecting nutrient deficiencies of soils and hence development of vegetation include:

(1) the amounts of the various macronutrients present in mineral soils
(2) their forms and combinations
(3) the processes by which these elements become available to plants
(4) the soil solution and its pH.

The organic population of the soil is responsible for dissolution and synthesis of humus -- essential for plant growth. Organisms in soil consist of plant and animal life; however, by far the greater proportion of these belong to plant life. Plant life consists of roots of higher plants, algae, fungi, actinomycetes of many kinds, and bacteria.

All of these factors affecting soil development are important in terms of assessing the revegetation rates in the House Mountain area.

Groundwater

Both regional and local groundwater flow patterns affect the erodibility of geologic materials in that the availability and chemical composition affects soil-forming processes. Furthermore, piping caused by groundwater discharge can contribute significantly to erosion.

Time

The erodibility of deposits will vary with time because slope angles, soils, vegetative cover, climate and so on change with time.

Climate

Climate is the overriding factor which controls most of the factors previously outlined, such as development of vegetative cover, soil forming processes, groundwater flow and so on. It should be stressed that both macroclimate and microclimates are important. For example, a south-facing slope will have different climatic conditions than a north-facing slope.

At any specific site, all these factors have a bearing on the erodibility of the deposits; however, the relative importance of the various factors can be expected to vary at different localities.

During the field investigations, it was observed that there was some degree of consistency in the nature of the erosion of specific types of geologic materials. These observations are summarized in the following section.

General Observations on the Erodibility of the Geologic Deposits

Muskeg

No observations were made on erosion of muskeg deposits as they are confinded to flat, low-lying areas and consist of thick vegetative material (Fig. 3). Lack of steep slopes prevent them from being eroded. In general, man-made features such as roads or wellsites were not present in these areas since construction difficulties would have occurred if development proceeded. Areas of muskeg are, therefore, not expected to pose significant erosion problems.

Gravel

It was found that gravel deposits are not susceptible to severe erosion. In general, their highly permeable nature allows surface water to infiltrate rather than to flow downslope. Furthermore, bank drainage is good in gravel.

FIGURE 3. Well developed muskeg in the study area.

For these reasons, gravels often stand in relatively steep banks which are not susceptible to large-scale gullying and surface erosion (Fig. 4).

It was observed that if the root and topsoil cover is left on gravel deposits they will revegetate quickly, provided the slope is not excessively steep. However, on bare gravel slopes revegetation is poor, likely due to the lack of fine particles which retain moisture and poor development of soils which supply nutrients required to sustain plant life.

Coarse Sand

Coarse sands are not prone to extensive erosion. The most likely explanation is that coarse sands, being highly permeable, minimize surface water runoff and hence gullying and erosion.

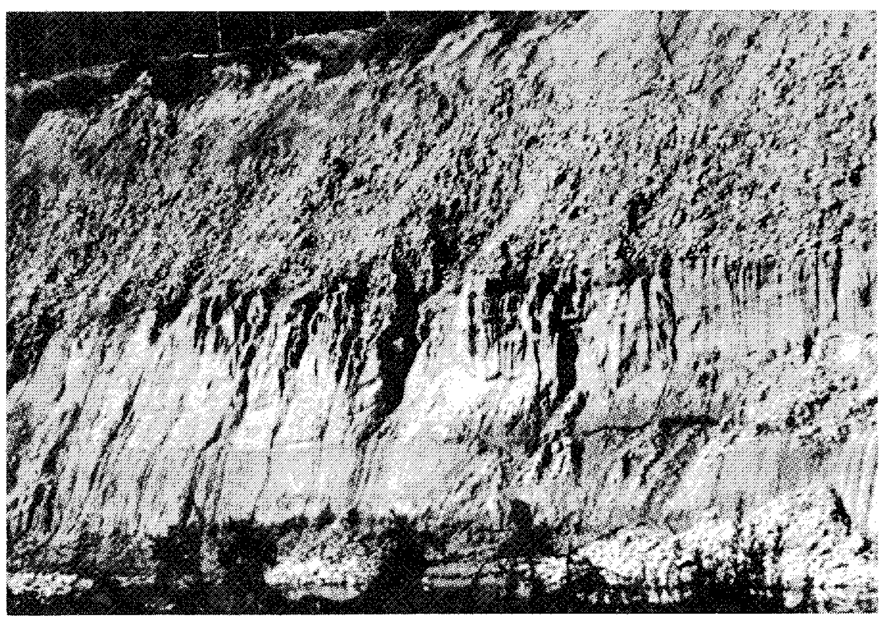

FIGURE 4. Alluvial gravels overlying sandstone and shale on Island Creek. (Note the lack of gullies in the gravel in contrast to well developed gullies in the sandstone. Smaller gullies have also developed in the shale near water level.)

If root and topsoil cover is left on coarse sand, it will revegetate rapidly provided the slope is not so steep that the cover is removed by subsequent runoff. However, if root and topsoil cover is absent, the sands revegetate slowly. In general, the coarser the sand the less susceptible it is to erosion, but the longer it takes to revegetate.

Till

On gentle slopes (<10°) till is prone to minor gullying.

Surface water carries the fine silt and clay particles more readily than the coarser gravels and boulders. The result is that a lag of coarse material is eventually formed on the till surface which inhibits further erosion (Fig. 5). On steeper slopes, the gullies are generally deeper; however, a lag of coarse material also forms inhibiting further erosion.

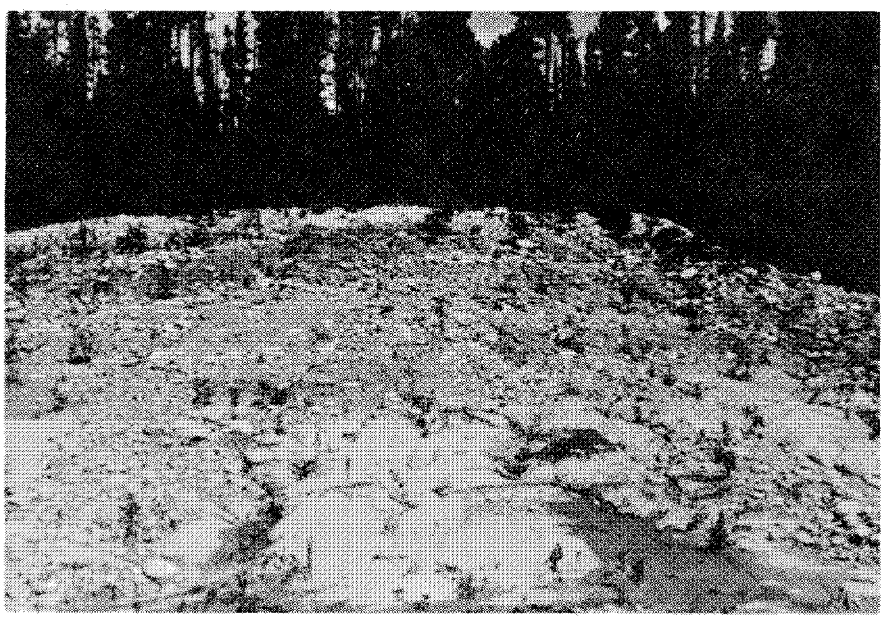

FIGURE 5. Shallow gullying on a gentle till slope. (Note the protective cover of gravel and boulders that have begun to form on the surface of the till.)

Revegetation of till surfaces occurs quite rapidly if roots and topsoil are not removed, even if the slopes are relatively steep.

Even when the roots and topsoil are removed, till on relatively shallow slopes revegetates readily (Fig. 6). This is likely due to the moisture retention properties of the till and the high percentage of fine-grained materials which aid soil-forming processes.

The bottom of the gullies revegetate most rapidly, partially due to higher moisture content in the till (Fig. 7).

In summary, erosion problems are not severe in glacial till, except in isolated instances on excessively steep slopes.

FIGURE 6. Shallow sloping till surface that has begun to revegetate in spite of removal of the root and topsoil cover.

FIGURE 7. Exposed till surface.
(Note the lack of gullies where a protective lag has developed on the till surface (near top of photo). Gullies have developed on the steeper till slope; however, the gullies have begun to revegetate. Near the bottom of the photograph, the relatively flat till surface has begun to develop a protective vegetative cover.)

Clay

Glaciolacustrine clays are susceptible to both slumping and gullying. Generally, lacustrine clays have a relatively high plasticity index with a correspondingly low shear strength. As a result, they are prone to slumping on steep slopes.

The low permeability of the clays enhances surface water runoff causing deep V-shaped gullies to develop on exposed slopes as shown on figure 8.

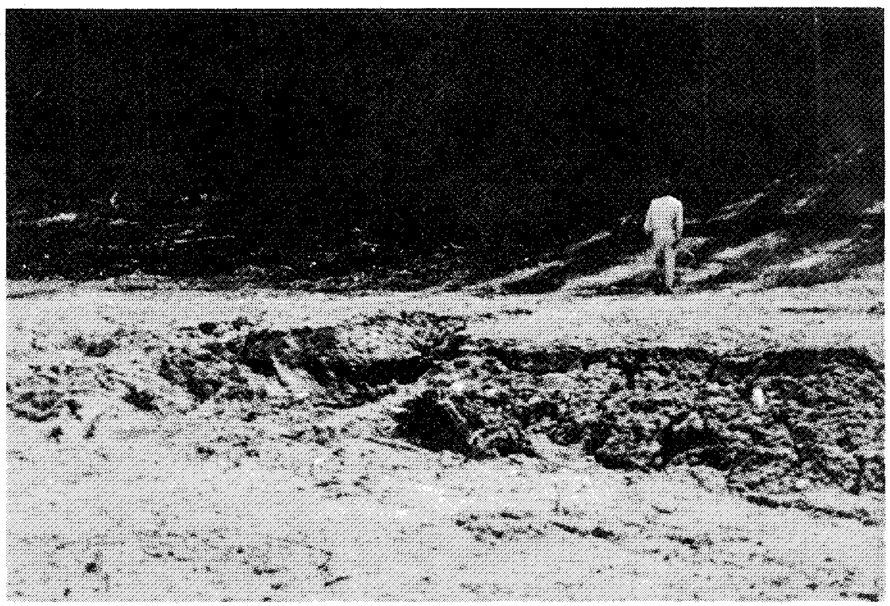

FIGURE 8. Deep gully eroded in lacustrine clay.

The fine grain size of the clays enhances soil-forming processes and retention of moisture resulting in relatively high revegetation rates on shallow slopes.

Bedrock Shale and Mudstone

Bedrock shales and mudstones are prone to extensive slumping and landslides as well as to gullying by surface water runoff.

Shales and mudstones occur extensively in Western Canada where they cause stability problems for slopes. Considerable research has been conducted on the behavior of these materials (Hardy *et al.*, 1962; Scott and Brooker, 1968); however, predictions of the engineering performance of these over-consolidated sediments cannot be made with reasonable confidence. Studies by Scott and Brooker (1968) concluded that the prime geologic factors affecting the engineering behavior of the shales and mudstones are depositional environment, lithology and stratigraphy, stress history, structure, climate, geomorphology, and groundwater. The effects of these factors on slope stability are outlined in table 1.

The shales and mudstones are relatively impermeable, which enhances surface water runoff and the formation of gullies (Figs. 4, 9). In addition, the high percentage of bentonite in these sediments causes them to swell and shrink with variations in moisture which tends to disrupt the sediments, so aiding particle removal. Gullying occurs even on gentle slopes unless a mantle of organic debris is left on the surface.

The shales and mudstones revegetate slowly, perhaps partially due to poor moisture retention characteristics and an imbalance of nutrients required to sustain plant life. Data obtained by Lindsay[2] indicate that samples of the Wapiti Formation collected to the south of the study area were low in fungi and bacteria content -- both important constituents in aiding vegetation development. Relatively high sodium content was also observed in the bedrock which may be another factor contributing to relatively slow revegetation rates.

Fine Sand

Noncemented fine-grained sands are highly susceptible to erosion (Fig. 10). These materials are quite permeable which helps to prevent surface runoff, but their fine grain size and lack of interparticle bonding allows them to be easily eroded by water and wind. Large gullies were observed in fine sands on moderate to steep slopes. Silt and clay in most fine sands allow some moisture to be retained making revegetation possible but relatively slow.

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[2] J. D. Lindsay, Head, Soils Division, Alberta Research

Table 1. Geological Factors Controlling Slope Stability and their Engineering Consequence

GEOLOGICAL FACTORS		INFLUENCE	ENGINEERING CONSEQUENCE
1. Depositional Environment	(a) Marine deposition.	High sodium conc. in pore fluid.	High osmotic swelling potential
	(b) Fine-grained clastic sediments and volcanic ash.	Clay sizes dominant, montmorillonite abundant.	High plasticity soils.
	(c) Slow rate of sedimentation.	Sediments generally of uniform texture and structure.	Low permeability.
	(d) Relatively shallow depth of burial.	Lithification incomplete, interparticle bonds weak.	Low shear strength, high rehydration swelling potential.
2. Lithology and Stratigraphy	(a) Bentonite layers interstratified with clay shales.	Retards downward movement of groundwater; leaching along top of bentonite layers.	Zones of high plasticity, high swelling pressure, low shear strength.
	(b) Fine-grained sandstone layers widely spaced.	Drainage layers widely spaced.	Layers of relatively high shear strength related to distribution of sandstone.
3. Stress History	(a) Loading by younger sediments.	Consolidation.	Increase in shear strength with loading.
	(b) Diastrophism and preglacial erosion.	Removal from marine environment, leaching, dilatancy, sediments in condition of overconsolidation.	Residual stresses relieved only in near surface zone.
	(c) Glacial erosion and loading.	In some areas consolidation loads may exceed those imposed by sediments.	May cause increase in O.C.R.
	(d) Glacial unloading.	Initiation of residual stress relief; sediments in condition of over-consolidation.	Residual stress concentrations.
	(e) Postglacial rebound.	Terrain uplift - erosion base level lowering, increase in groundwater gradients.	Stream erosion accelerated, downcutting exceeds rate of residual stress relief.
	(f) Valley erosion.	Exposure of zone of high residual stress. Fracture development parallel with the valley.	High lateral stresses in valley walls.
4. Structure	(a) Attitude of bedding.	Controls outcrop width of formation.	Older beds of formation may occur below near-surface zone of stress relief.
	(b) Fracture development.	Vertical planes of weakness.	Loss in mass shear strength.
5. Climate	(a) Precipitation.	Affects rate of groundwater movement and leaching.	Seasonal pore pressure fluctuations leaching may decrease shear strength.
	(b) Temperature.	Alternate wetting and drying produces fractures. Freeze/thaw action in fractures.	Decrease in shear strength in near-surface fracture zone.
6. Geomorphology	(a) Position of base level.	Controls depth of valley and in part, rate of erosion.	Failures occur only where base level of erosion is below critical height of slope. Critical height, however, is not constant.
	(b) Stream channel configuration.	Asymmetrical cross valley profile, steep undercut slopes, toe erosion.	Decrease in shearing resistance of slope.
	(c) Terrace development.	Reduction in effective slope height.	Decrease in shear stresses.
	(d) Rate of erosion.	Rate of downcutting may exceed rate of residual stress relief in valley walls.	Increase in shear stresses.
	(e) Slope exposure.	Exposure to insolation may depress groundwater flow regimen.	Increase in effective stress due to decrease in neutral stresses.
7. Groundwater	(a) Quantity.	Seasonal variations in flow may increase leaching and pore pressures.	Decrease in shear resistance.
	(b) Quality.	Differences between groundwater chemistry and pore-water chemistry can create osmotic swelling pressures.	Decrease in shear resistance.

from Scott and Brooker (1968)

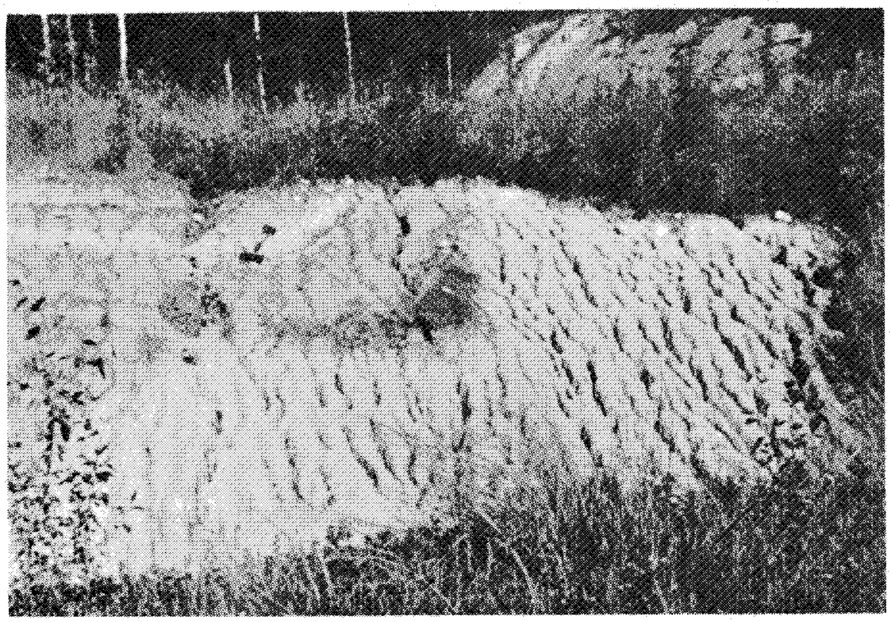

*FIGURE 9. Contorted mudstone and sandstone beds exhibiting shallow gullying in the mudstone.
(The denser network of gullies in the sandstone is apparent.)*

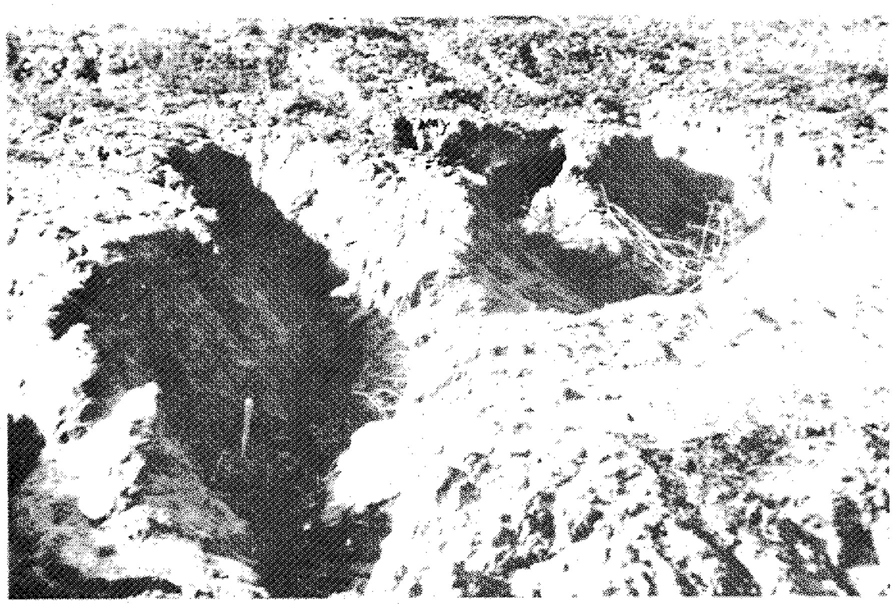

*FIGURE 10. Extensive erosion of fine-grained glacial sands.
(Slope angle is greater than 30°)*

Silt

Cohesionless silts and silty clay deposits were found to be highly susceptible to erosion. Deep V-shaped gullies form in these materials due to easy removal of the particles by surface water runoff (Fig. 11).

Silts are also prone to the formation of ice lenses which disrupt the material; thawing of the lenses in spring results in the soil becoming supersaturated and more susceptible to erosion. The silts were observed to revegetate readily (Fig. 12), especially on shallow slopes (<10°).

Sandstone

The poorly cemented bedrock sandstones were found to be highly erodible. Surface runoff easily removes the clay mineral cement from between the

FIGURE 11. Extensive erosion of glaciolacustrine silts in the Swan Hills area to the south.[3]
(Note how revegetation is occurring in spite of the steep slope.)

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[3]At this particular site, Dr. D. St.-Onge (Geological Survey of Canada) observed that considerable erosion occurred during spring runoff when the previous year's vegetation had been killed by frost.

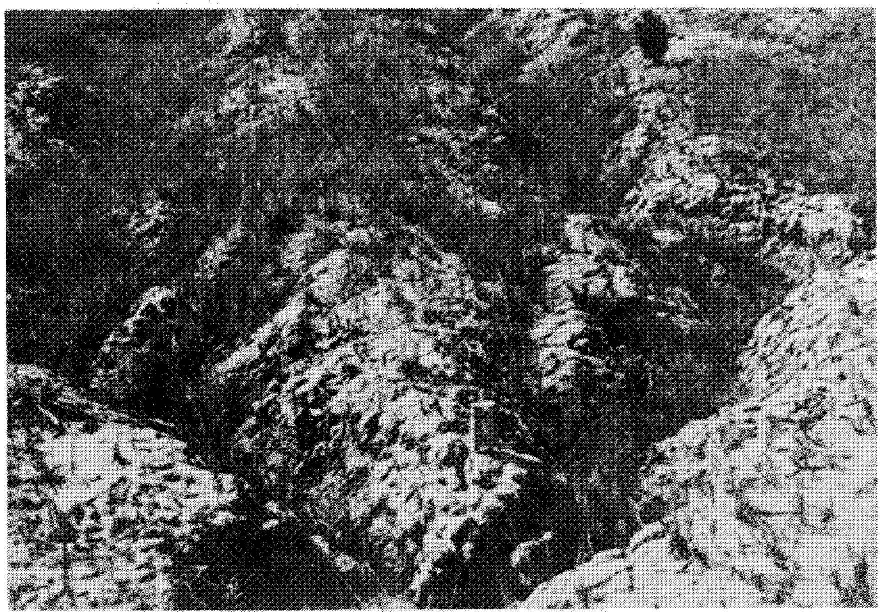

FIGURE 12. Erosion of silts on a shallow slope. (Note how revegetation is taking place differentially, and is most successful in the bottom of the gullies.)

sand grains and allows the finer-grained sands to be washed away. Erosion ranges from minor gullies to badland features and broad deep washouts (Figs. 13, 14). Slumping and landslides are uncommon in thick sandstone sequences suggesting the shear strength of the sandstones is higher than the shear strength of the shales and mudstones. St.-Onge[4] (pers. comm.) has observed that although erosion occurs rapidly in the sandstone, it is to some extent self-arresting once a base level of erosion has been established.

Sandstone exhibits poor revegetation characteristics, perhaps due to poor moisture retention properties, an imbalance of macronutrients such as excess exchangeable sodium, and low bacteria and fungi counts. Even shallow slopes of less than 10° are badly eroded because soil formation and plant growth

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[4]Dr. D. St.-Onge, Geological Survey of Canada, Ottawa.

FIGURE 13. Well developed gullies in sandstone.

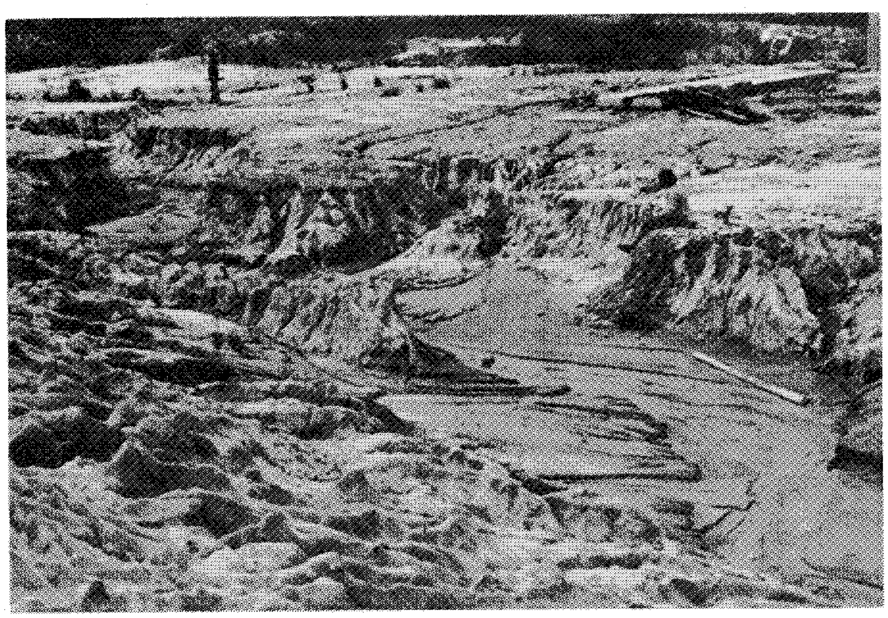

FIGURE 14. Badland topography and washouts developed in sandstone.

are unable to keep pace with erosion. Sandstone was rated as the deposit most susceptible to erosion in the House Mountain area.

Based on the nature of erosion of the various geologic deposits as outlined, it is possible to rate the geologic deposits in terms of their susceptibility to erosion (Table 2). The writers recognize the complexity of the interrelated factors affecting the erodibility of the deposits at any given location; however, they feel that the following rating of the deposits in terms of their susceptibility to erosion represents, in a general way, the conditions likely to be encountered in the field. The division of the slopes into shallow and steep is a generalization because the changes in erodibility are gradational with slope changes.

In applying this rating system in the field, *all the factors relating to the process of erosion described previously should be assessed at each particular site; however, the importance of the type of geologic material present cannot be overemphasized.*

METHODS OF CONTROLLING EROSION

Natural erosion is a continuing process in the study area, the most extensive being along stream valleys. This erosion consists of downcutting by the streams and bank erosion caused by oversteepening of the valley walls. Erosion is greatest on steep banks with no vegetative cover, usually where the slopes are being undercut by streams (Fig. 15).

Extensive natural erosion of bedrock deposits is also occurring on steep slopes, especially on the flanks of House Mountain (Fig. 16).

Much additional erosion occurs when slopes are cut into and vegetation removed during construction of roads, wellsites, battery installations, cutting of seismic lines, and so on. The susceptibility of the various deposits to erosion, together with the factors contributing to their

Table 2. Erosion Susceptibility Classification

Geologic Material	Shallow Slopes (less than 10°)		Steep Slopes (greater than 30°)	
	Erosion Characteristics	Rate of Revegetation (topsoil and roots removed)	Erosion Characteristics	Rate of Revegetation (topsoil and roots removed)
muskeg	no gullying	N.A.	N.A.	N.A.
gravel	no gullying	negligible to slow	very shallow gullying self-arresting	negligible
coarse sand	very shallow gullying	slow	moderate to deep gullying	negligible
till	very shallow gullying self-arresting	rapid	moderate gullying partially self-arresting	slow
clay	moderate gullying	rapid	deep gullying prone to slumping and landslides	slow
bedrock shale	moderate gullying	slow	deep gullying prone to slumping and landslides	negligible
fine sand	moderate to deep gullying	slow	deep gullying	negligible
silt	deep gullying	moderate	severe gullying	negligible
bedrock sandstone	deep to severe gullying	negligible to slow	severe gullying	negligible

FIGURE 15. Erosion of sand and gravel deposits along the undercut bank of the Swan River.

FIGURE 16. Erosion of bedrock deposits on steep slopes near House Mountain.

erodibility, were outlined in a previous section. The following methods of preventing or arresting erosion apply to all types of deposits; however, the results obtained will depend on the type of geologic deposits and the interrelationship of the several factors affecting erosion at any particular location.

(1) In general, an effort should be made to cut man-made slopes at as low an angle as possible; however, it must be realized that low slope angles may result in removal of vegetation over a large surface area causing even greater erosion. Each particular setting should be evaluated individually in order to optimize erosion control by the proper combination of low slope angle and surface exposure.

(2) Development in areas of highly erodible materials (see classification) or steep natural slopes should be minimized.

(3) Activities such as logging operations and seismic exploration do not require complete removal of root and topsoil cover; therefore, these materials should be left undisturbed wherever possible to minimize erosion and to aid revegetation (Fig. 17). These activities should be minimized wherever possible in areas of steep natural slopes.

(4) After a slope has been cut and the surface exposed, erosion can be inhibited by spreading a layer of roots and topsoil on the exposed slope (Fig. 18). This material will also aid revegetation of the slopes. Because this material is readily available if stockpiled during construction, it represents one of the most effective and least expensive methods of erosion control.

(5) Trees placed at approximately right angles to the slope on exposed surfaces have been used to inhibit erosion. The writers observed that poplar trees with few branches were only moderately effective in controlling erosion because fine particles could be carried downslope

FIGURE 17. *Natural revegetation occurring along a seismic line near Swan Hills. (Note poorer natural revegetation on the steeper slope.)*

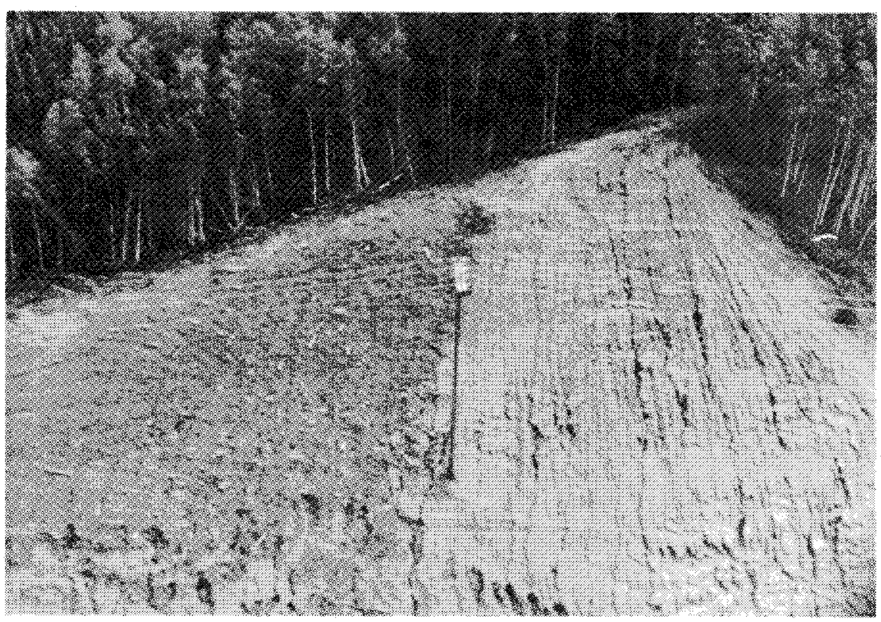

FIGURE 18. *Exposed slope in glaciolacustrine silt. (Note how a layer of roots and topsoil which has been spread on the slope on the left side of the photograph has significantly reduced gullying by surface water runoff. Note piping due to groundwater discharge near the base of the slope.)*

underneath the trees (Fig. 19). However, coniferous trees with many small branches are much more effective in controlling erosion since they trap many of the fine particles and gullying is minimized (Fig. 20).

(6) Gravel or boulder berms placed at periodic intervals in ditches can be useful in inhibiting erosion. However, they must be placed with their lowest point occurring in the center of the ditch or water will flow around them causing washouts (Fig. 21).

Both the design and interval of placement of these berms are being investigated by Dr. D. St.-Onge of the Geological Survey of Canada.

(7) Because erosion tends to self-arrest as a base level of erosion is approached, the base of eroded slopes should not be disturbed when attempts are being made to control further erosion. Similarly, reworking of gullied slopes only serves to enhance further erosion and gullying.

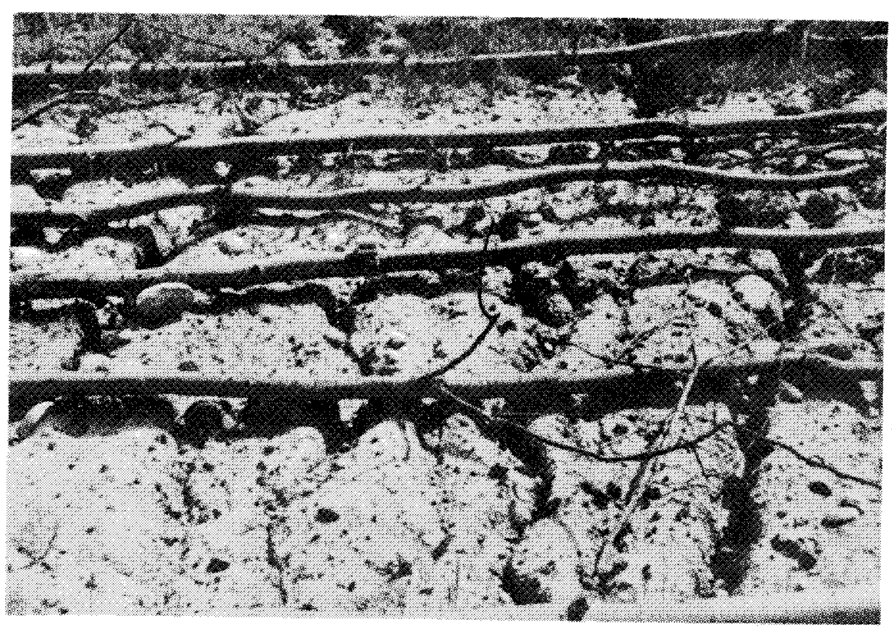

FIGURE 19. Gullying of till slope below poplar trees used to inhibit erosion.

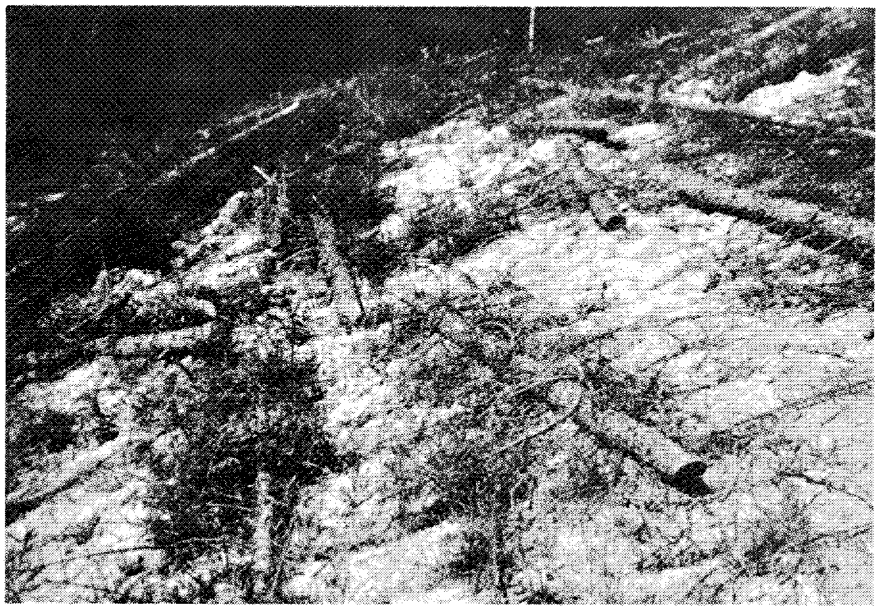

FIGURE 20. Coniferous trees placed on an exposed slope to reduce erosion. (Note how revegetation of the slope is taking place - especially near the trees.)

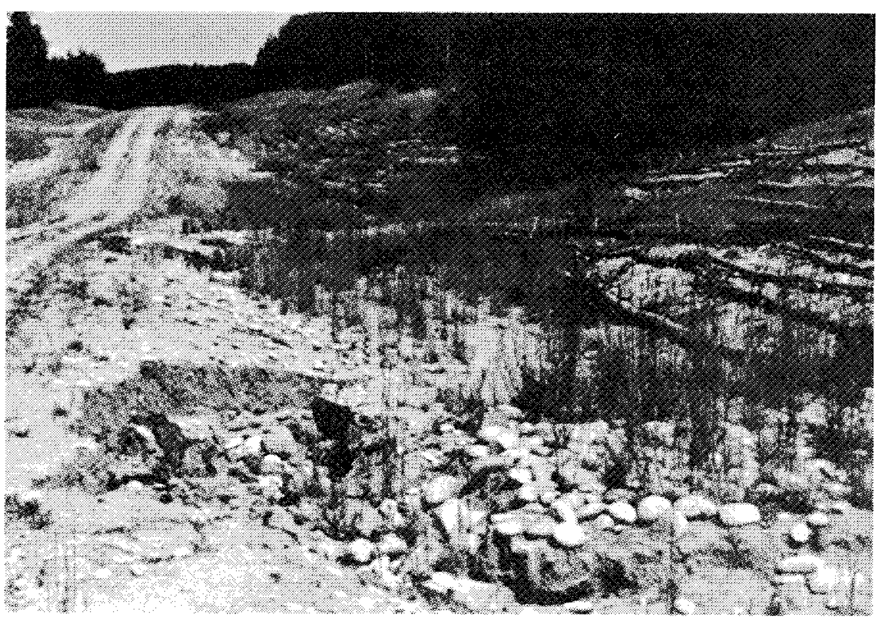

FIGURE 21. Washout due to improper placement of a boulder berm in a ditch.

(8) Attempts have been made to terrace shale and mudstone slopes that have been exposed. However, this technique should be avoided because the slopes are oversteepened in localized areas resulting in even greater erosion by slumping and gullying.

If these techniques for prevention or control of erosion are applied in the field in the early stages of any development, the writers feel that erosion problems could be minimized.

SUMMARY AND RECOMMENDATIONS

Surficial geologic deposits in the House Mountain area were mapped on a scale of 1:50,000 (Fig. 2).

The interrelated factors that control erosion were briefly discussed and the various geologic deposits rated in terms of their susceptibility to erosion. The effect of slope on erosion and natural revegetation characteristics of the deposits were included in the erosion susceptibility classification (Table 2).

The writers feel that the map of the surficial deposits, when used in conjunction with the erosion susceptibility classification, can be utilized as an aid in formulating land use plans for the area because areas likely to be most susceptible to erosion have been delineated. However, the map is not meant to replace an on-site inspection at any location where development takes place, since glacial and postglacial deposits vary significantly in grain size and lithology over short distances resulting in specific characteristics for any particular site. Furthermore, all the other factors effecting erosion vary from site to site.

It is important that the type of material present at each site, as well as the interrelated factors affecting erosion, are recognized at the time when development occurs so that suitable measures can be taken to prevent or inhibit erosion.

The writers feel that further studies are warranted in the area to provide specific data on the engineering properties, physical properties, and chemical composition of the geologic deposits. This information would be of considerable value in assessing further the factors affecting erosion.

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Alberta RESEARCH

LEGEND

RECENT

EROSIONAL FEATURES AND DEPOSITS

13 Gully, creek valley, scarp: *thin colluvial cover on valley slopes; thin alluvial materials along streams; mixed glacial and bedrock materials in slump areas*

Generally steep slopes; severe gullying common; active stream undercutting causing slope instability; negligible to moderate revegetation depending on materials present

12 Eroded bedrock: *interbedded sandstone and shale, minor siltstone and coal; thin colluvium on steep gully walls, mixed glacial and bedrock materials in slump areas; small areas of uneroded glacial deposits*

Generally steep slopes; deep to severe gullying common; negligible revegetation

11 Eroded till-hummocky moraine: *mixed clay, silt, and sand, pebbles and boulders; lenses of sand, gravel, and local bedrock; thin colluvial cover on eroded slopes; generally more than 40 feet thick; topography undulating to gently rolling and highly dissected by erosion along stream valleys, gullies and steep slopes*

Intermediate to steep slopes; moderate gullying; material partially self-arresting depending on sand and gravel content; slow to moderate revegetation

10 Eroded till-ground moraine: *clay, silt, and sand, pebbles and boulders; variable in thickness, but generally less than 40 feet; often occurs as sheet deposit on relatively steep bedrock slopes, till sheet highly dissected by erosion along stream valleys, gullies, and steep slopes; thin colluvial cover on eroded slopes; topography level to undulating*

Shallow to steep slopes; shallow gullying, self-arresting in level areas, moderate to severe in steep areas particularly when bedrock is exposed; slow to rapid revegetation depending on slope

ALLUVIAL FEATURES AND DEPOSITS

9 Muskeg

8 Stream alluvium: *silt, clay, sand, and gravel along streams*

Generally level to very shallow slopes; negligible to shallow gullying in coarse sands and gravel; severe erosion of silts and clays possible; slow to moderate revegetation of the silts, sands, and clays, very slow revegetation of gravels

7 Lake and slough deposits: *silt, clay, organic muck and marl, minor silt and clay stream alluvium*

Generally flat to very shallow slopes; moderate to deep gullying possible, depending on silt content; moderate to rapid revegetation

PLEISTOCENE

GLACIOLACUSTRINE DEPOSITS

6 Silt and clay: *bedded silt and clay, minor sand*

Flat to shallow slopes; moderate to deep gullying possible depending on silt content; moderate to rapid revegetation

5 Silt: *bedded silt, minor fine- to medium-grained sand and clay beds*

Flat to shallow slopes; deep gullying; moderate revegetation

GLACIAL DEPOSITS

4 Till-hummocky moraine: *mixed clay, silt, and sand, pebbles and boulders; lenses of sand, gravel, and local bedrock; generally more than 40 feet thick; occurs as a mantle on eroded bedrock slopes; topography undulating to gently rolling*

Shallow to steep slopes; shallow to moderate gullying depending on slope, erosion may be self-arresting, depending on slope and sand and gravel content; slow to rapid revegetation

3 Till-ground moraine: *clay, silt, and sand, pebbles and boulders; variable in thickness but generally less than 40 feet, topography level to undulating*

Generally shallow to intermediate slopes; shallow gullying which is self-arresting; rapid revegetation

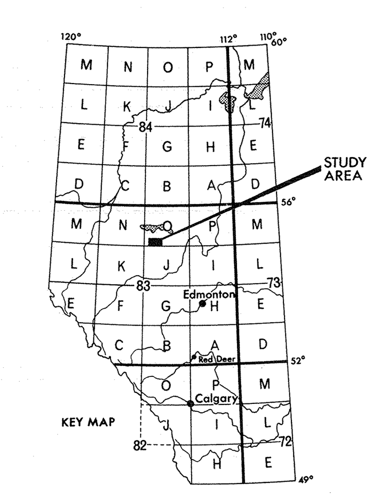
2 Till over bedrock: *clay, silt, and sand, pebbles and boulders; occurs as a thin veneer overlying bedrock; generally less than 10 feet thick*

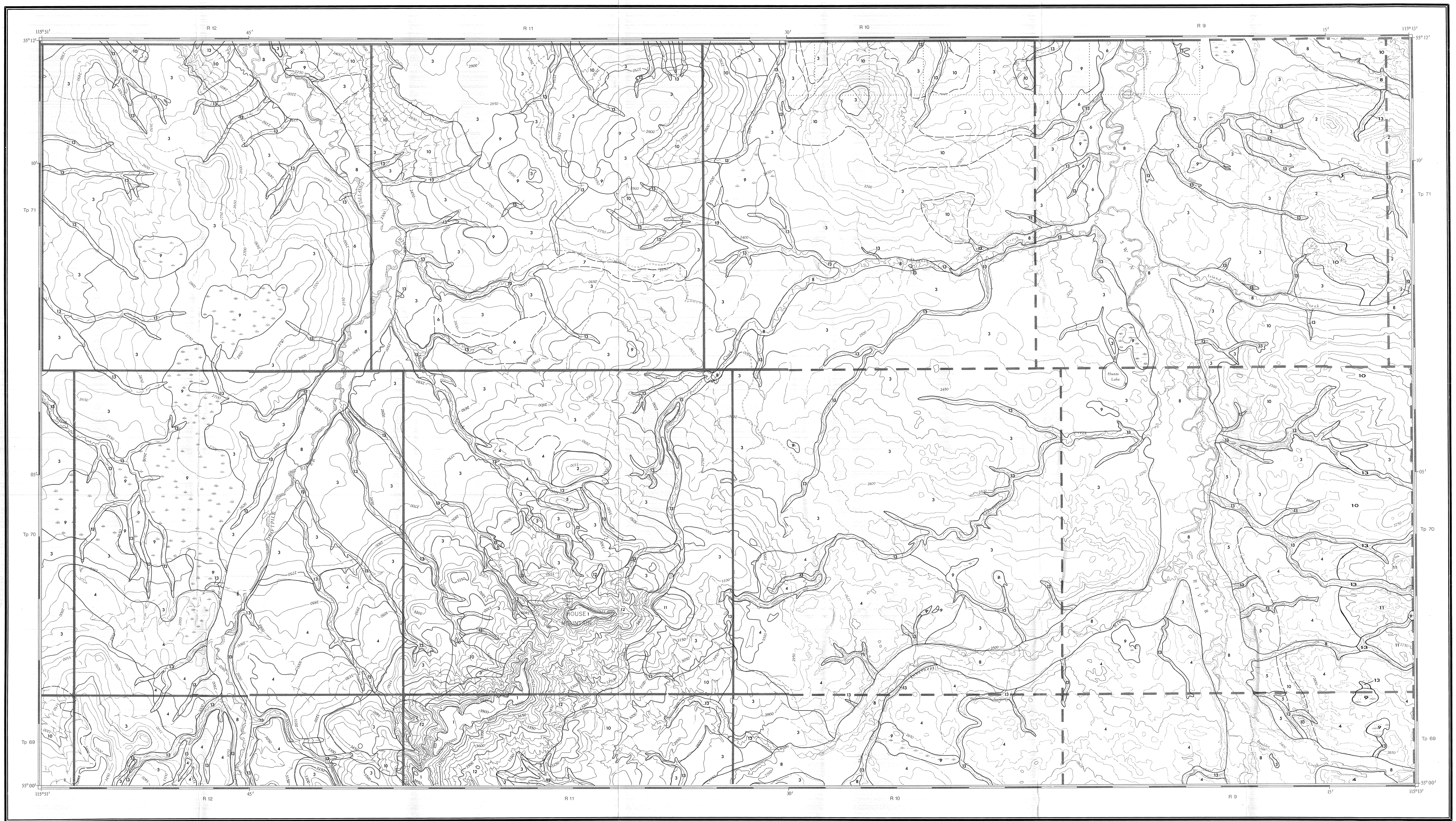
Intermediate to steep slopes; moderate to severe erosion depending on till thickness; slow revegetation if till is on surface, negligible for bedrock

TERTIARY AND CRETACEOUS

1 Bedrock plateau: *sandstone and shale, minor siltstone; approximately horizontally bedded, overlain by a thin veneer of recent sand, silt, and clay formed by bedrock weathering; topography flat except where minor gullying by surface water has occurred*

Flat to shallow slopes; deep to severe gullying possible; slow to negligible revegetation





SCALE 1:50,000

Miles 1 0 1 2 3

Metres 1000 500 0 1000 2000 3000 4000

LEGEND

River or stream ....

Intermittent river or stream ....

Lake ....

Township boundary ....

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by C. P. Kathol and R. A. McPherson

FIGURE 2

SURFICIAL GEOLOGY HOUSE MOUNTAIN ALBERTA