Alberta Research Council - Geology Division

FORT CHIPEWYAN ORNAMENTAL-BUILDING STONE PROJECT

CHIPEWYAN RED GRANITE

GEOLOGICAL RECONNAISSANCE OF

SLUICE SITE NUMBER TWO

by

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July 12, 1976

Alberta
RESEARCH COUNCIL

Contents

Figures

HISTORICAL SUMMARY

1970

Reconnaissance geological mapping by the Research Council of Alberta revealed and outlined a red granite pluton in the Precambrian Shield rocks just north of Fort Chipewyan, outside of Wood Buffalo National Park. This pluton of attractive appearing granite crops out over an area of approximately 50 square miles, 3 to 4 x 15 miles, elongated in a northeasterly direction (Fig. 1).

1971

In recognition of its potential value as ornamental-building stone, selected reconnaissance ground traverses and spot checks were made in the southern portion of the pluton (closest to Fort Chipewyan) to determine whether or not bedrock conditions would be generally favourable for quarrying operations. The situation looked encouraging.

1972

Exploration was undertaken by helicopter, with follow-up ground checks, to identify specific potential quarry sites. Out of eight sites identified for ground reconnaissance investigation three were chosen for closer study. Finally, on the basis of color, texture and rock fracture patterns, one site (sluice site number one, Fig. 1, south site) was selected for hydraulic sluicing and detailed mapping and evaluation. The geological assessment proved to be positive and a limited core drilling program to 25 foot depths was recommended to check out the extension of rock quality and the horizontal fracture spacing.

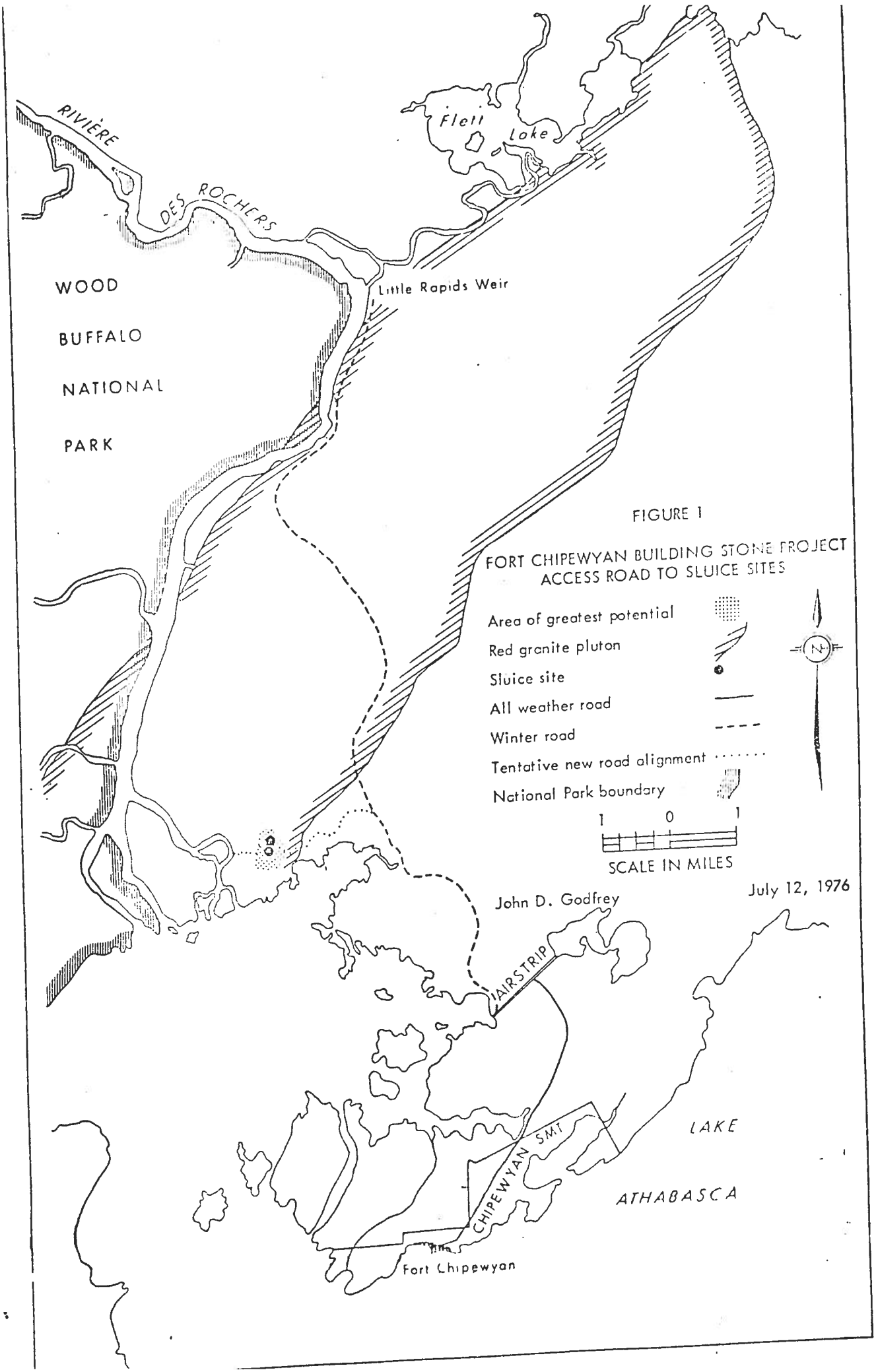

FIGURE 1

FORT CHIPEWYAN BUILDING STONE PROJECT
ACCESS ROAD TO SLUICE SITES

1973

The Alberta Department of Business and Industry in a preliminary economic feasibility study did not find the economic outlook for granite building stone development at Fort Chipewyan to be particularly promising.

1974-75

The Alberta Northern Development Group established a $70,000 fund to examine the technical-economic feasibility and socio-economic impact of a granite building stone industry near Fort Chipewyan.

This study was awarded to Angus Butler Engineering Ltd. (Edmonton), in association with Gemini North Ltd. (Vancouver). Site one was studied in detail.

Elements of this study included:

Diamond drill coring of sluice site number one

Consultation by Quebec quarrymaster Mr. Bev Haselton

ASTM tests (strength, abrasion, freeze-thaw) by Mr. Fred Hanes, Ottawa (in progress)

Economic feasibility study

Social-economic impact on Fort Chipewyan.

The bulk of these studies were carried out in late 1974 and in the first half of 1975.

Although sluice site number one proved to contain very good quality granite building stone it appeared to have limited tonnage capability. Since long-term supplies of good quality material are highly desirable at one quarry location, further ground exploration was undertaken in September-October, 1975 to find a site with significantly larger tonnage potential.

This exploration led to discovery of a site 600 feet farther north, (Fig. 1, north site) which was hydraulically sluiced and termed "sluice site number two." Onset of winter conditions prevented geological mapping and evaluation until June, 1976, and the results of that study are contained in the body of this report.

Geologic Features of Sluice Site Number Two

Evaluation of a granite ornamental-building stone requires consideration of the following geologic factors. Many of these features are illustrated in the accompanying photographs (26 to 49) of Appendix II.

Fracture Frequency and Distribution

Fracture spacing varies widely in plan view from a fraction of an inch to over 6 feet. The scale used in the mapping of this site (1 inch = 20 feet) has allowed the representation of all the megascopic fractures in the outcrop, shown in figure 2 and projected into cross sections figure 3. The fractures are accurately positioned with reference to the 10 foot grid marks painted on the cleaned rock surface (grid marks measured by steel tape).

Most fractures are of the systematic variety, making an orthogonal pattern with sets striking north 20 degrees west and north 70 degrees east, and are defined as master[1] to major to minor in importance. They are steeply dipping 75 to 90 degrees. Many of the master joints are multiple fracture surfaces and have notable gape at the surface. Rarely, indications of shearing are evident.

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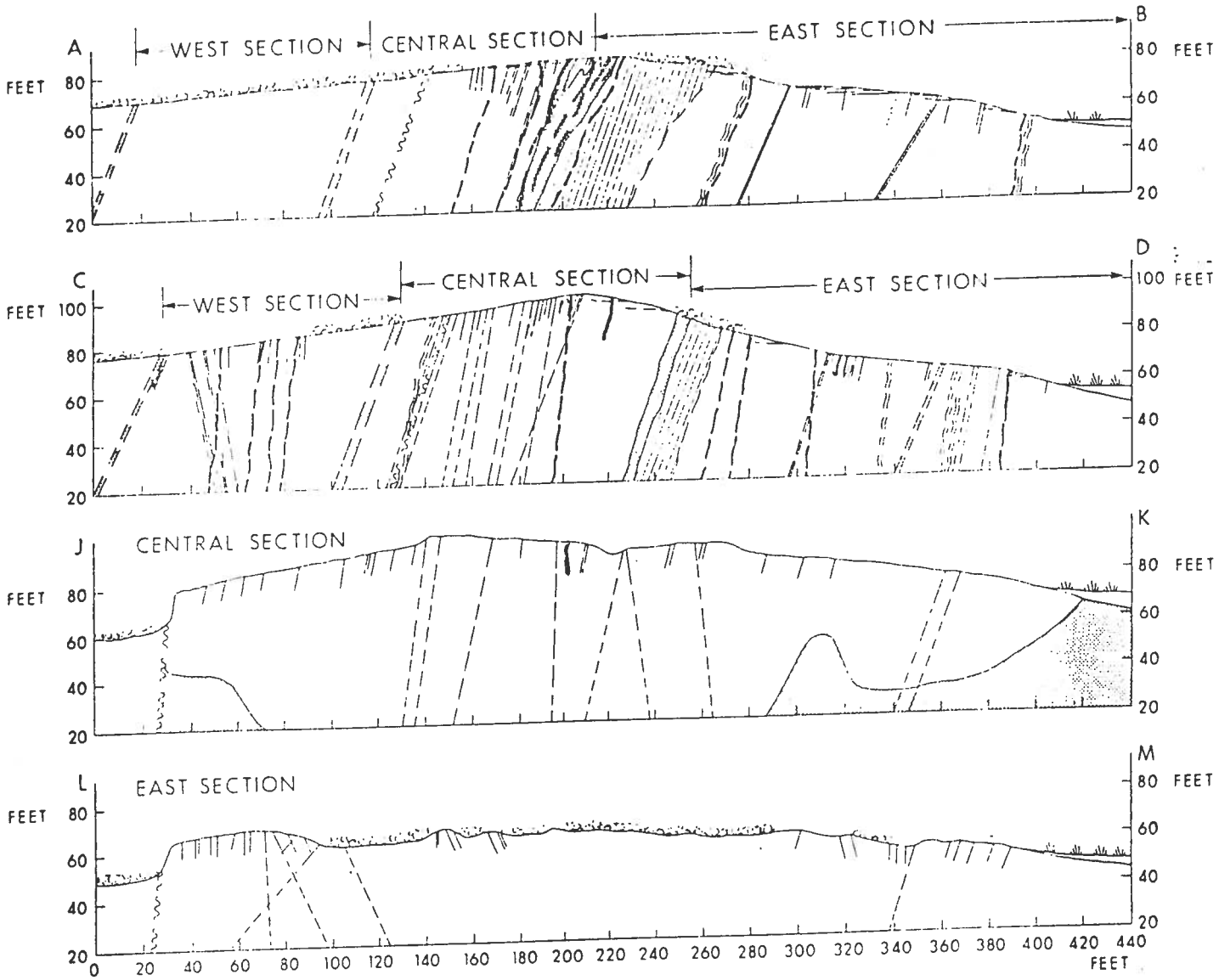
[1]Note: Master joint typically in excess of 50 feet long; major joint from 10 to 50 feet long; minor joint less than 10 feet long.

FIGURE 3

VERTICAL GEOLOGICAL CROSS SECTIONS THROUGH SLUICE SITE NUMBER TWO

(To accompany figure 2)



FORT CHIPEWYAN BUILDING STONE PROJECT

Chipewyan Red Granite

Amphibolite

Grey Alteration Zone

Gneissosity in granite

Quartz veins, pods, etc.

Pegmatite

Fault

Metamorphic foliation

Joints - dip known - extensions shown to depth

- dip unknown - limited depth projection

John D Godfrey

July 12, 1976

Most major joints occur as single fracture surfaces, with no parallel adjacent shears. Both master and major joints are expected to penetrate many tens of feet in depth from the outcrop surface. Minor joints extend for several feet along the outcrop surface; they may parallel either the master or major joints, or trend in an entirely different orientation. These minor joints are expected to extend up to 10 feet or so in depth.

Some of the master and major joints make up fracture sheeting (zone of closely spaced fractures), mostly oriented parallel to the two established principal joint directions (Fig. 2). Northerly jointing tends to dominate in the southern part of the sluice site, whereas easterly jointing dominates in the northern portion. Easterly jointing tends to terminate against northerly jointing rather than the reverse, but mutual cross-over intersections are also common.

Several steep topographic slopes from 5 to 20 feet high and up to 250 feet long at sluice site number two give information on the gently to flat dipping joints (quarry term "bedding plane joints"). These data show that bedding plane joint spacing in excess of 3 feet can be found within 4 feet of the existing surface in over 80 percent of the 14 points of observation taken at the site (Fig. 2). As is commonly recognized in existing quarries, the orientation of bedding plane joints is usually similar to that of general topographic slopes.

Gneissic Banding

Diffuse-margined mafic (dark) mineral (chloritic biotite) banding, typically from less than 1 inch to 2 inches wide has been noted and is plotted on figure 2. These bands are usually weakly developed, grouped

in zones a few inches or feet in width, and extend parallel to the rock foliation, usually for a few feet only but may be up to tens of feet in length.

Gneissic banding is a generally undesirable feature in an ornamental stone, but the indicated frequency and distribution at the sluice site suggests that there are numerous large areas free from banding. Nowhere does an intense color contrast exist between adjacent mafic and felsic bands. These bands are most commonly encountered in north trending zones within or adjacent to the grey discoloration zones which are discussed below (e.g. west edges of both central and east sections), but they can also be found at scattered places over the sluice site (Fig. 2).

Rock Color Variation

Rock color has been evaluated from 276 cut hand specimens (Fig. 4) and the color range has been divided into four categories: deep-red, medium-red, light-red and pink; grey phases are also present. However, by far the greater amount of rock has been classified in the deep-red and medium-red categories. Variations in color do not appear to occur over short distances and large areas are underlain by the desirable deep- and medium-red rock (Fig. 5). Experience has shown that weathering and any attendant discoloration is normally confined to a skin up to 1/4 inch thick and hence a reliable color judgement can be made on hand-sized specimens.

Light grey color variations are attributed to contact alteration effects adjacent to basic dykes. Discoloration to a light pink color in shallow glacially smoothed depressions in the outcrop are due to organic acid leaching which penetrates less than 1 inch from the surface.

Grain Size Variation

The usual coarse-, medium- and fine-grained classification (> 5, 5 to 1, and < 1 mms) has been applied to hand specimens and the results are incorporated in figure 5. The majority of the rock is medium grained; the grain size variations are combined with color variations in the formulae used to develop "desirable, intermediate and undesirable" categories plotted in figure 5.

Foliation

Foliation is rarely a prominent feature of the red granite in so far as the rock is typically poor in mafic minerals. Characteristically the rock contains about 1 percent mafic mineral which is mostly dispersed rather than concentrated into streaks, bands, or lenses which would emphasize the foliation. The texture tends to be massive to very poorly foliated or lineated; in the latter case quartz may show a preferred alignment of elongated, rod-shaped grains parallel to the (chloritic) biotite foliation. Elimination of the faint 'grain effect' due to quartz lineation in polished surfaces of building stone can be effected by cutting slabs perpendicularly to the lineation.

Mafic Mineral Variations

The mafic (dark) mineral content has a total range (in hand specimen) from zero to between 5 and 10 percent, but the typical concentration is in the 1 to 2 percent range.

The development of gneissic banding is associated with relatively mafic-rich portions of the outcrop.

The mineralogical composition of the Chipewyan Red Granite has been determined by modal analysis and appears in Appendix I.

Pegmatites

The incidence of pegmatites in the outcrop is relatively low. Those pegmatites exposed typically occur as fairly straight dykes with lengths from 20 to 70 feet and uniform widths from 4 to 8 inches. There is a virtual absence of small-scale pegmatite bodies (patches, pods or lenses). The pegmatites are of uniform granitic composition, being either mafic poor or totally lacking in mafic minerals. Pegmatite dykes appear only in part to be structurally related to either the foliation or the principal faults.

Quartz Veins

Quartz veins are commonly 1/2 to 10 feet long (maximum of 60 feet) and from 1/2 to 2 inches thick, having a maximum of 10 inches thickness. They are composed of quartz with minor feldspar locally. The orientation of quartz veins is controlled by the two principal shear-fracture directions, the northerly direction being most common.

Basic Dykes

Narrow, straight, amphibolitic dykes have intruded at least five of the principal fault structures which strike north 10 to 20 degrees west at sluice site number two. These dykes are generally from 1 to 4 feet thick and though poorly exposed in the vegetated fault line gullies they are expected to extend continuously for over 4000 feet along strike. Post-intrusion fault movement is evident as the dyke rock is typically sheared and locally shows a megascopic shear foliation.

Drastic color alteration in the red granite accompanies the principal dykes intruded along the north-northwest striking faults. Grey granite zones extend up to 25 feet away from the dyke-intruded faults and have been mapped for strike lengths of over 300 feet. Some sections

of dyke appear not to have an adjacent grey granite alteration zone, and some fault zones appear to have an associated grey alteration zone but lack a dyke intrusion. Consequently, the grey alteration zone appears most likely related to fault-controlled hydrothermal alteration rather than to direct contact with a dyke - though a genetic connection between the alteration and intrusive activity can be anticipated.

Pyrite

One of the most undesirable features of an ornamental-building stone is the presence of pyrite (iron sulfide) because of the rust stain that usually develops from it upon weathering. From megascopic examination of outcrop and numerous hand specimens, the Chipewyan red granite essentially lacks pyrite. It was seen in minute grains at only one location.

Geological Mapping Evaluation

Sluice site number two, measuring roughly 400 feet square, is intruded by three major north-trending basic dykes that conveniently subdivide the area into three major blocks - western, central, eastern (Fig. 2). These major dykes have weathered to form depressions or gullies which are thickly vegetated and typically have little outcrop. Two additional minor basic dykes also intrude the eastern section of red granite.

West Section

About 25 feet of relief is present above the surrounding lowland over an area of 120 x 80 feet; some 60 percent of the outcrop appears suitable for building stone quarry purposes. This granite knob lacks a

steep face for easy side-hill quarry access except on the west side (10 feet high) adjacent to the poorest (high fracture density) quality building stone material.

The fracture pattern is dominated by the northerly trending set; although the easterly fractures are of lower density, they tend to be long (major to master) and therefore will have considerable influence on the breakage and quarrying character of the building stone blocks.

Quartz veins, gneissosity and pegmatites are of low frequency in the most promising part of the West Section (Fig. 2).

Grain size and color characteristics vary but large areas appear suitable for building stone application. The areas where a few hand specimens are classified as "undesirable" make up a minor proportion of the West Section and it has been possible to outline a prospective quarry site 120 x 50 feet in size (Fig. 6).

Central Section

About 40 feet of relief is present above the surrounding lowland within an area of 380 x 110 feet; over 50 percent of the Central outcrop area appears suitable for building stone quarry purposes. The Central Section stands highest relative to the adjacent lowland and a 10 to 20 foot high escarpment at the north end would provide excellent access for a side-hill quarry operation.

The fracture pattern is dominated by the north-trending system, although easterly striking fractures are also present in the northern half of the outcrop. These easterly striking fractures tend to be long and continuous and would be influential in determining size and shape of quarry blocks and mining methods.

Quartz veins, pegmatites and gneissosity tend to be locallized and concentrated in north-trending zones. Quartz veins and pegmatites in particular are concentrated along the east and west margins, adjacent to the basic dyke-fault zones, and along the southern end of the Central outcrop (Fig. 2).

Grain size and rock color characteristics exhibit a wide range but large areas of medium-grain size and medium red color appear suitable for building stone purposes, (Fig. 5). The small number of hand specimens classified as "undesirable" indicate areas of mixed rock color but they are not expected to interfere with the extraction of industrially acceptable proportions of commercial-grade building stone. A prospective quarry site 350 x 45 to 80 feet (average 70 feet) is outlined in figure 6.

East Section

A maximum relief of 25 feet is available above the surrounding lowland to the north and east, involving an area 360 x 170 feet. Over 60 percent of the cleared outcrop within the East Section would appear suitable for building stone purposes. An escarpment grading in height from 20 to 0 feet along the north end provides good access for a side-hill quarry operation.

The fracture pattern is dominated by the easterly fracture system, the north-trending fractures becoming locally significant as a second set.

Quartz veins, pegmatites, gneissosity and two thin amphibolitic dykes are present but tend to concentrate in northerly trending zones along either the two thin amphibolite dykes or the major dyke-fault zone along the western margin of the East Section, (Fig. 2).

Although grain size and rock color exhibit the same degree of variation seen elsewhere at sluice site number two, there appears to be a higher proportion of the desirable qualities of homogeneous, medium-grain size and medium red color, (Fig. 5). The amounts of "undesirable" category rocks should not present undue problems in terms of interfering with the mining of a satisfactory proportion of commercial-grade building stone. An area of approximate size 350 x 140 to 70 feet (average 110 feet) is outlined in figure 6 as a prospective quarry site.

Conclusions and Summary

1. Hydraulic sluicing and cleaning of a large portion of the outcrop within an area of 400 x 400 feet at sluice site number two has permitted a critical geological evaluation. It has revealed the range of geologic character in this potential ornamental-building stone in outcrop in terms of rock color, texture, quartz veins, etc.

2. Bedding joint spacing (commonly 3 to 4 to 6 feet) is encouraging for production of building stone blocks.

3. Vertical joint frequency is expected to diminish with depth (especially beyond 10 feet beneath existing surface) because of the influence of both frost wedge action in the surface and near-surface fractures and decompressional jointing.

4. The need for confirmation of rock quality and fracture conditions at depth by means of a diamond drill core program are not so critical as at sluice site number one because of -

   (a) the experience gained from the drill core project at sluice site number one; and

(b) the availability of several steep rock faces at sluice site number two, including one face 250 feet long and up to 20 feet high.

5. Mineralogical and rock color 'defects' in terms of pyrite, grey zones, pegmatites, quartz veins, basic dykes, rock color, and textural variations, appear to be within commercially acceptable levels.

6. The depth extension of quality granite can be anticipated, shown to some extent by the excellent quality of rock at the base of the 20 foot scarp at the north end of the east section.

7. A maximum local relief of 55 feet above the eastern muskeg and the presence of a 20 foot-high escarpment provides a good opportunity for the initial development of a side-hill quarry operation.

8. Working conditions in the quarry should be good; the pit should be virtually free of water during the many initial years of block production. The shallow eastern muskeg is not of major concern in terms of its water-producing capability.

9. Priority rating of the three prospective quarry areas at sluice site number two for building stone development is: East Section, Central Section, and last, West Section.

10. The combined tonnage potential of the three prospective quarry sites as side-hill operations alone is more than adequate for possible market needs in the forseeable future, even allowing for a most optimistic production level. The areas and corresponding reliefs of each of the three quarry sites are:

West Section - 120 x 50, relief 25 feet;

Central Section - 350 x 70, relief 40 feet;

East Section - 350 x 110, relief 25 feet.

11. Nearby knobs of granite outcrop (e.g. 1/2 mile north, and also adjacent to the south) suggest the ready availability of a second granite building stone material that has a pleasing pink color.

12. Several options are available for layout and storage areas for equipment, materials stockpiles, servicing facilities, etc., adjacent to the prospective quarry sites. Clearing of vegetation cover would be a minor undertaking.

13. A more-than-adequate water supply is available 2,500 feet to the west in the form of a large wet muskeg, and a branch of the Riviere des Rochers is located another 500 feet farther to the west.

14. Access to the prospective quarry sites from Fort Chipewyan is presently by a 14 mile boat trip plus a 3,000 foot hike. Year-round, overland access would use the existing 5 1/2 mile all-weather road from Fort Chipewyan to the airport, plus an additional 5 1/2 miles to the prospective quarry sites. A winter road already connects the airport northwest to the Little Rapids Weir (on the Rivière des Rochers) and probably passes within 2 miles of sluice site number two. This winter road alignment may prove useful in gaining access to the sluice site (Fig. 1).

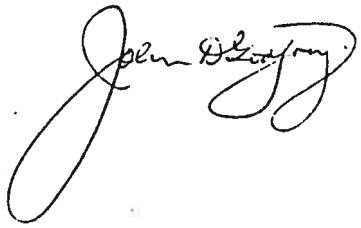
Recommendations and Outlook

1. As far as practical, strip and hydraulically clean the granite outcrop in the northern part of the East Section to provide continuous clean outcrop. All aspects of the surface rock character can then be examined in detail and will be meaningful in terms of a projected quarry operation.

2. Extensive engineering testing has already been carried out in accordance with ASTM procedures on samples of the red granite obtained from sluice site number one (600 feet south). These data should apply equally well to sluice site number two and there is no need to repeat these tests.

3. The Alberta Provincial Government has recently invited proposals from private industry for joint development of this granite resource. The prospective quarry sites are ready and available for inspection by interested parties.

4. If the outlook based on inspection by industry is favourable, then it is presumed that plans will proceed for detailed engineering and economic feasibility studies. The latter will include detailed on-site studies relative to mining methods, production schedules, quarry layout, mining equipment, water and power supplies, etc. requiring a variety of expertise, including that of a quarry master knowledgable in the development of granite building stone quarries.



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APPENDIX I.

PETROGRAPHIC (MODAL) ANALYSIS OF CHIPEWYAN RED GRANITE

The following modal analysis is an average of six analyses selected from Sluice Site Number 1, an outcrop approximately 600 feet south of Sluice Site Number 2. No compositional variations of the Chipewyan Red Granite are expected within these distances. These six modal analyses represent a total of 12,000 points.

Mineral	Volume Percent
Quartz	31.18
Potash feldspar (dominantly microcline)	34.4
Plagioclase	29.2
Biotite	2.7
Chlorite	0.9
Hornblende (present in one sample only)	0.2
Epidote	0.05
Muscovite	0.07
Accessories	1.3
Total	100.00

FORT CHIPEWYAN BUILDING STONE - CAPTIONS TO PHOTOGRAPHS

GEOLOGY OF SITE

John D. Godfrey

26. Part of the dock area at Fort Chipewyan. New, enlarged breakwaters have been built at Fort Chipewyan in the last two years, affording greatly improved dock facilities. Further improvements of the dock area in 1976 have included dredging and deepening of the harbour.

27. Federal D.P.W. Dredge 252 deepening the harbour at Fort Chipewyan, June, 1976.

28. Chipewyan Red Granite; relatively widely spaced, poorly developed vertical and bedding plane joints. Note planar, simple character of fracture surface traces.

29. Chipewyan Red Granite; widely spaced, poorly developed, vertical joints; one 2 foot wide zone of closely spaced bedding plane joints, otherwise widely spaced and poorly developed.

30. Chipewyan Red Granite; one well developed vertical joint, otherwise poorly developed vertical and horizontal joints. Note orthogonal pattern (i.e. approximate right angles) of joint intersection and characteristic planar, single surface of fractures.

31. Chipewyan Red Granite; unusual steep intersection of bedding plane joints with a well developed vertical joint. Dark stains on joint face are due to seepage and run-off from organic-filled depressions above.

32. Chipewyan Red Granite; widely spaced north-trending vertical joints; showing grouped parallel joints locally 'en echelon' in character.

33. Chipewyan Red Granite; general view looking north towards top of central section from extreme south end; showing painted base line.

34. Chipewyan Red Granite; widely spaced, poorly developed, vertical and bedding plane joints. Note orthogonal arrangement of joint surfaces.

35. Chipewyan Red Granite; two foot thick basic dyke (dark) intruding minor fault zone in east section.

36. Chipewyan Red Granite; detail of two foot thick dyke (dark, beneath hammer) intruding fault zone within granite of east section.

37. Chipewyan Red Granite; detail of a steeply dipping master joint trace.

38. Chipewyan Red Granite; widely spaced minor, major and master joints having a mutual orthogonal arrangement.

39. Chipewyan Red Granite; narrow basic dyke intrusion along closely spaced multiple fractured, fault zone.

40. Chipewyan Red Granite; major, north-trending master joint with unusual wide zone of multiple fracture surfaces.

41. Chipewyan Red Granite; detail of a single-surface master joint intersected by minor bedding plane joints; showing portion of painted base line.

42. Chipewyan Red Granite; for purposes of mapping the cleaned-off outcrop, 10 foot grid points were measured and painted on the outcrop. Strings were also placed between 20 foot grid points to form 20 foot squares.

43. Chipewyan Red Granite; showing the trace of poorly developed bedding plane joints at their intersection with vertical to steeply dipping joints.

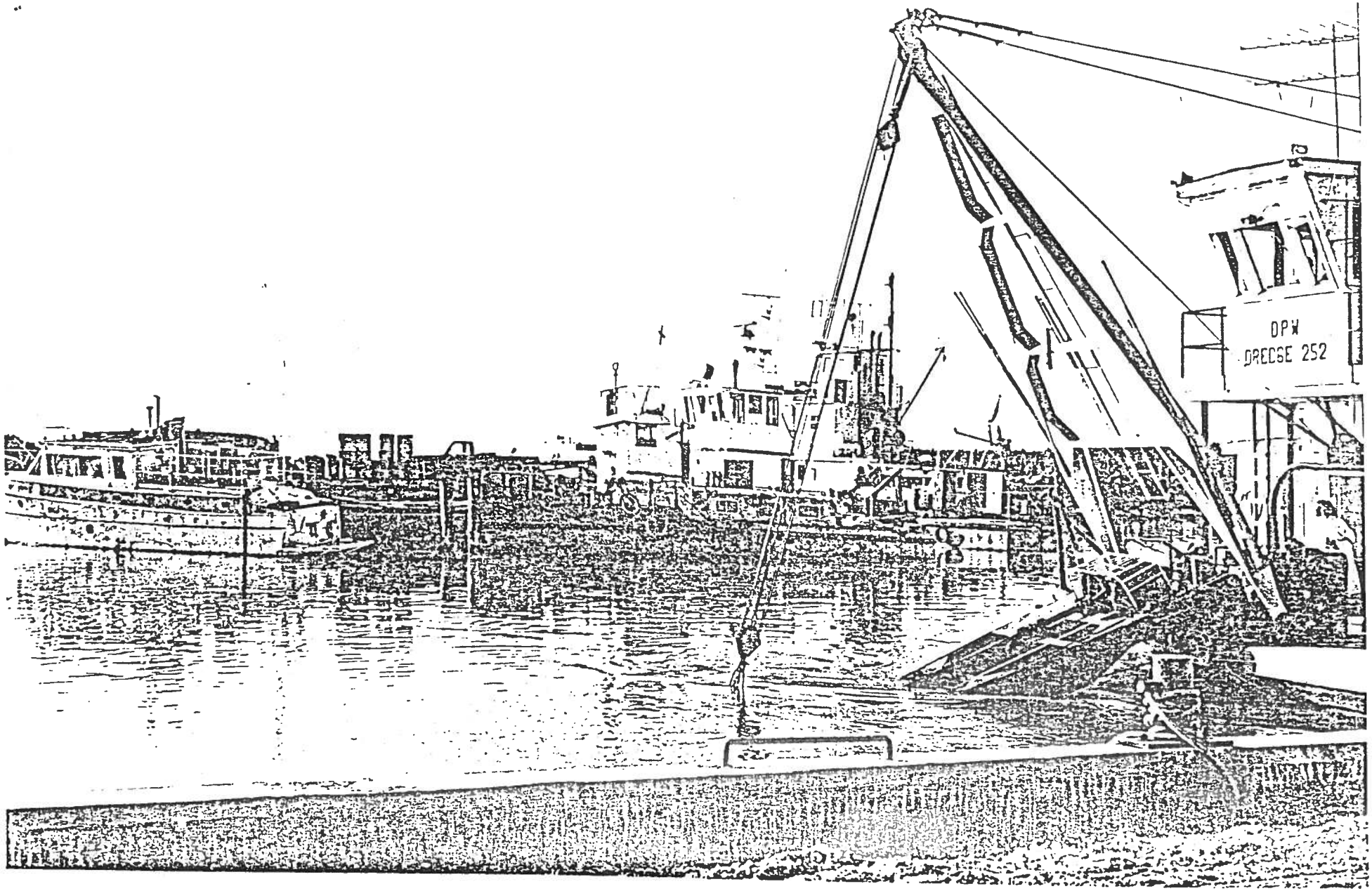
44. Chipewyan Red Granite; glacial scouring has partly eroded and cleaned off a bedding plane joint in this small granite knoll.

45. Chipewyan Red Granite; granite outcrop shows a series of three moderately dipping parallel joint traces and surfaces.

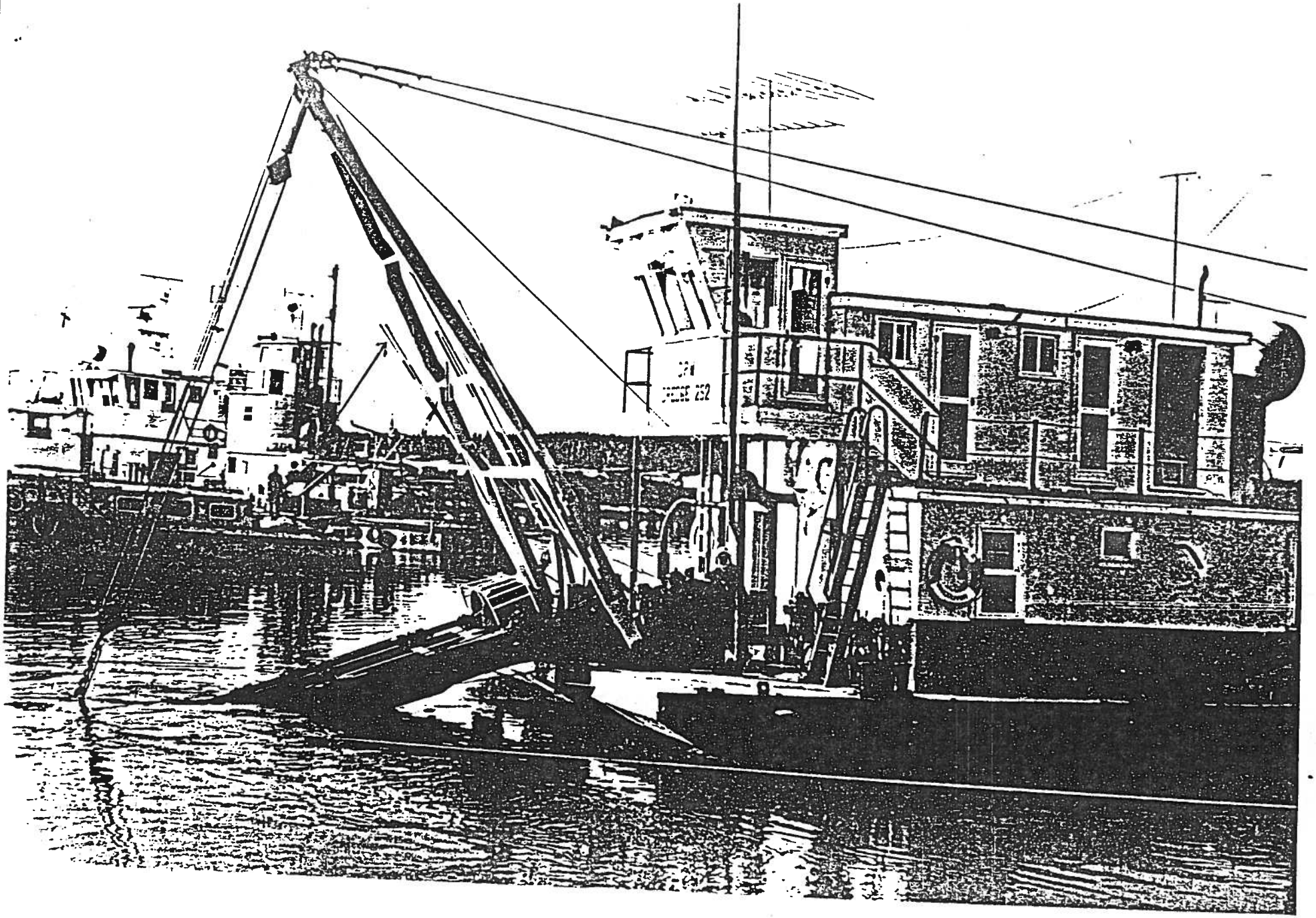
46. Chipewyan Red Granite; weakly developed, but discernible, alternating light and dark gneissic mineral banding in granite: an undesirable feature in commercial building stone.

47. Rivière des Rochers; three sets of well-developed joints (two vertical, one
48. horizontal), on a high riverside bluff of granite gneiss adjacent to a fault
49. parallel to the length of the bluff. Situated about 7 miles south from sluice site number two.

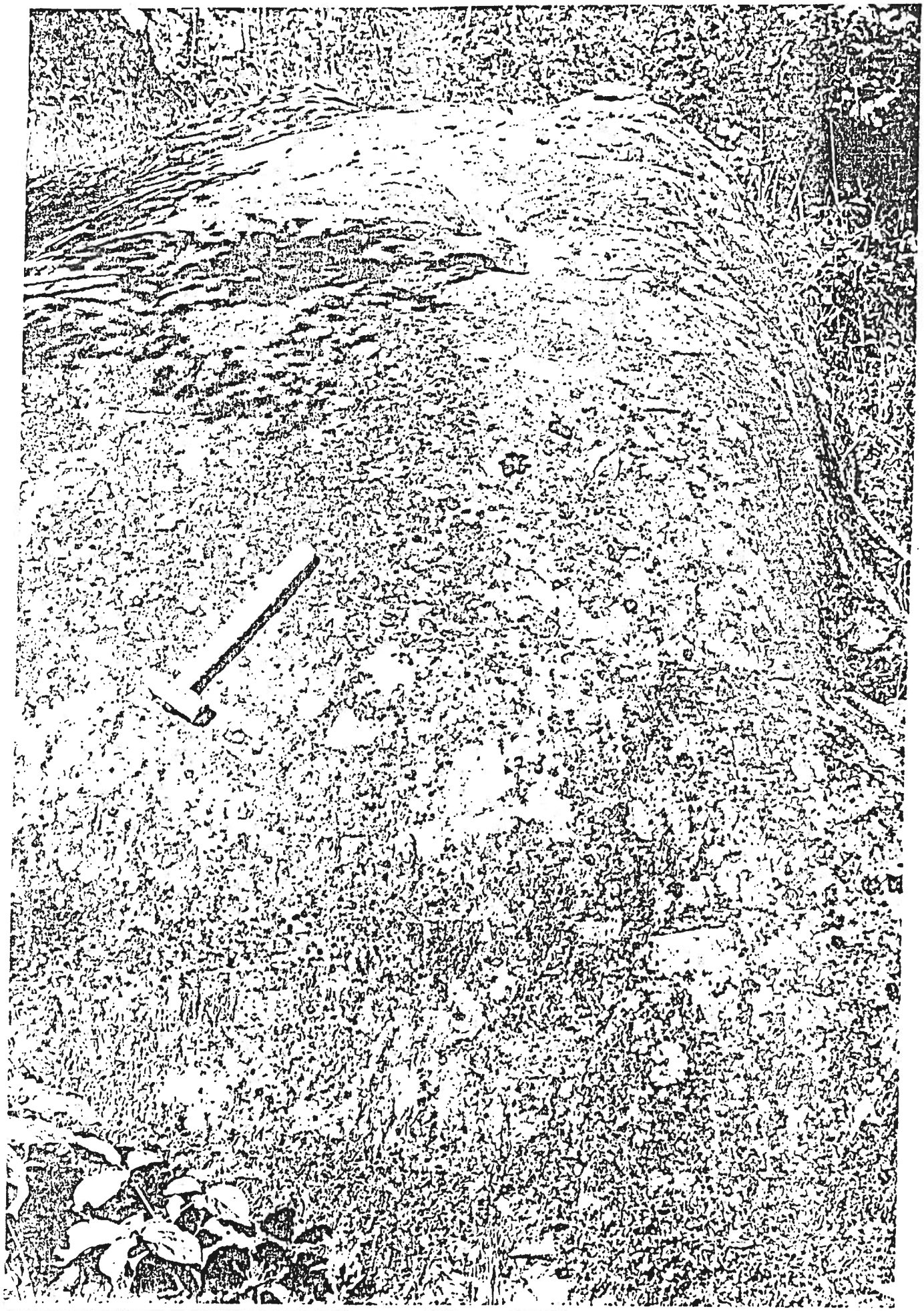
Photograph 26. Part of the dock area at Fort Chipewyan. New, enlarged breakwaters have been built at Fort Chipewyan in the last two years, affording greatly improved dock facilities. Further improvements of the dock area in 1976 have included dredging and deepening of the harbour.


DPW
DREDGE 252

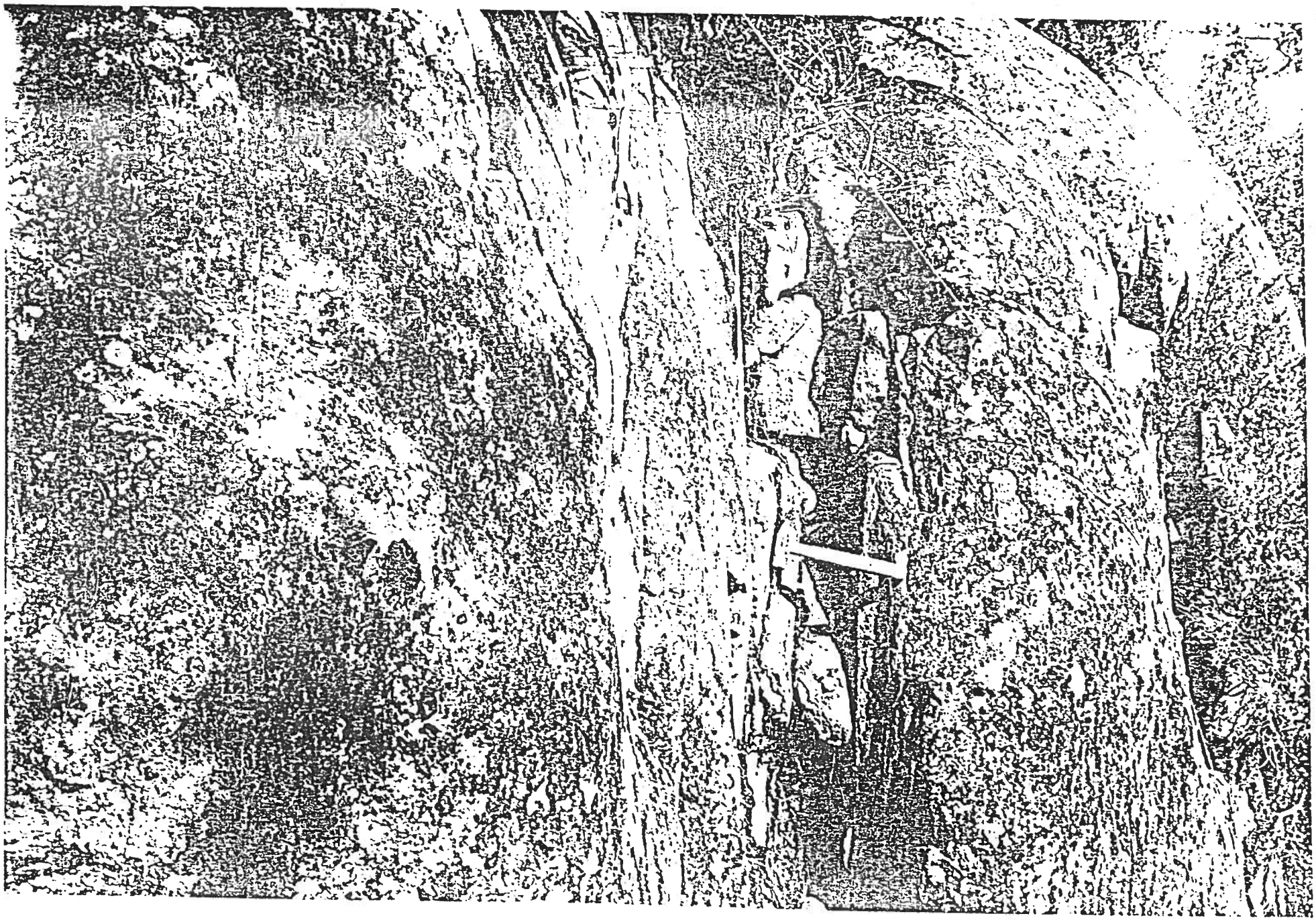
Photograph 27. Federal D.P.W. Dredge 252 deepening the harbour at Fort Chipewyan, June, 1976.



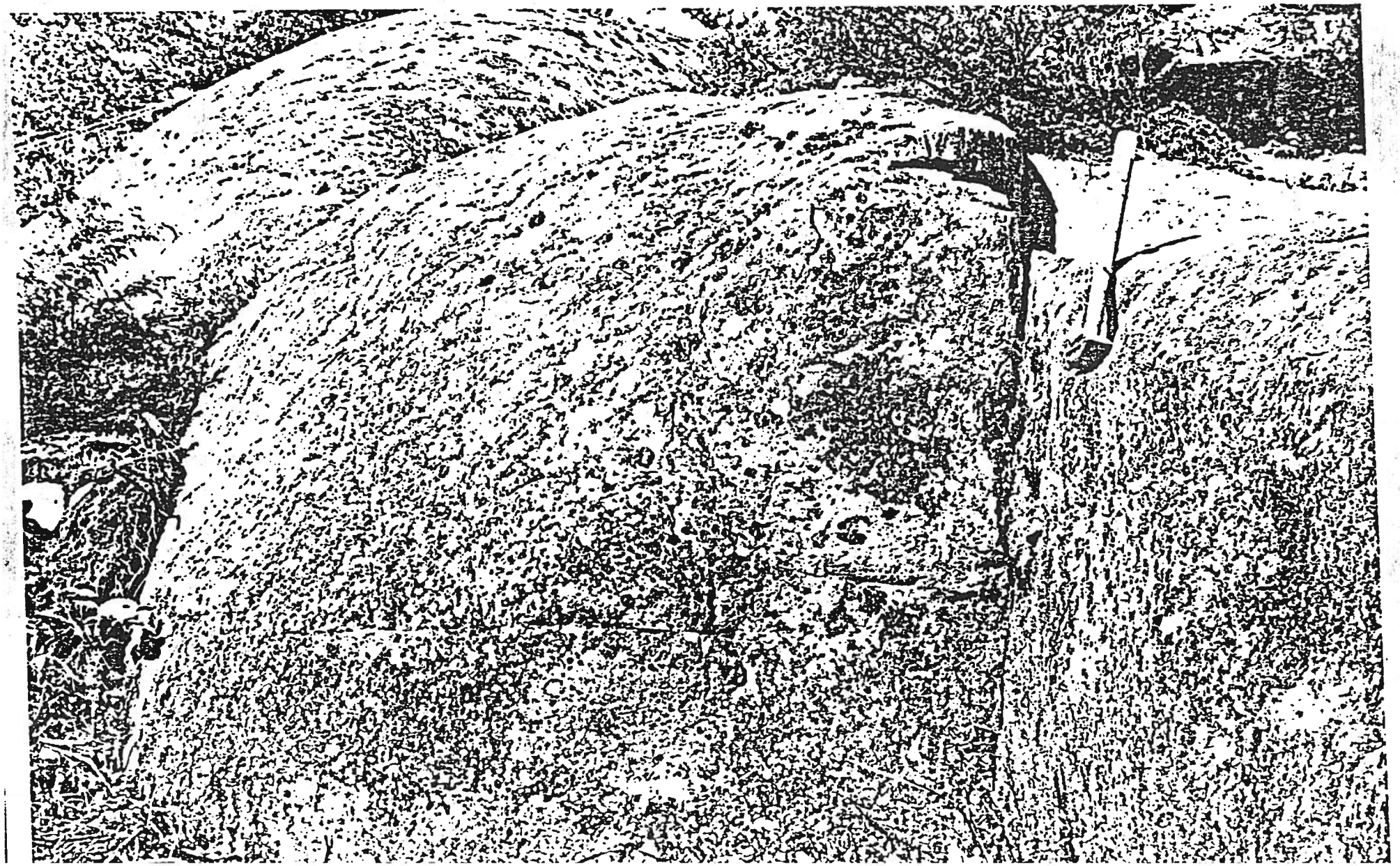
Photograph 28. Chipewyan Red Granite; relatively widely spaced, poorly developed vertical and bedding plane joints. Note planar, simple character of fracture surface traces.



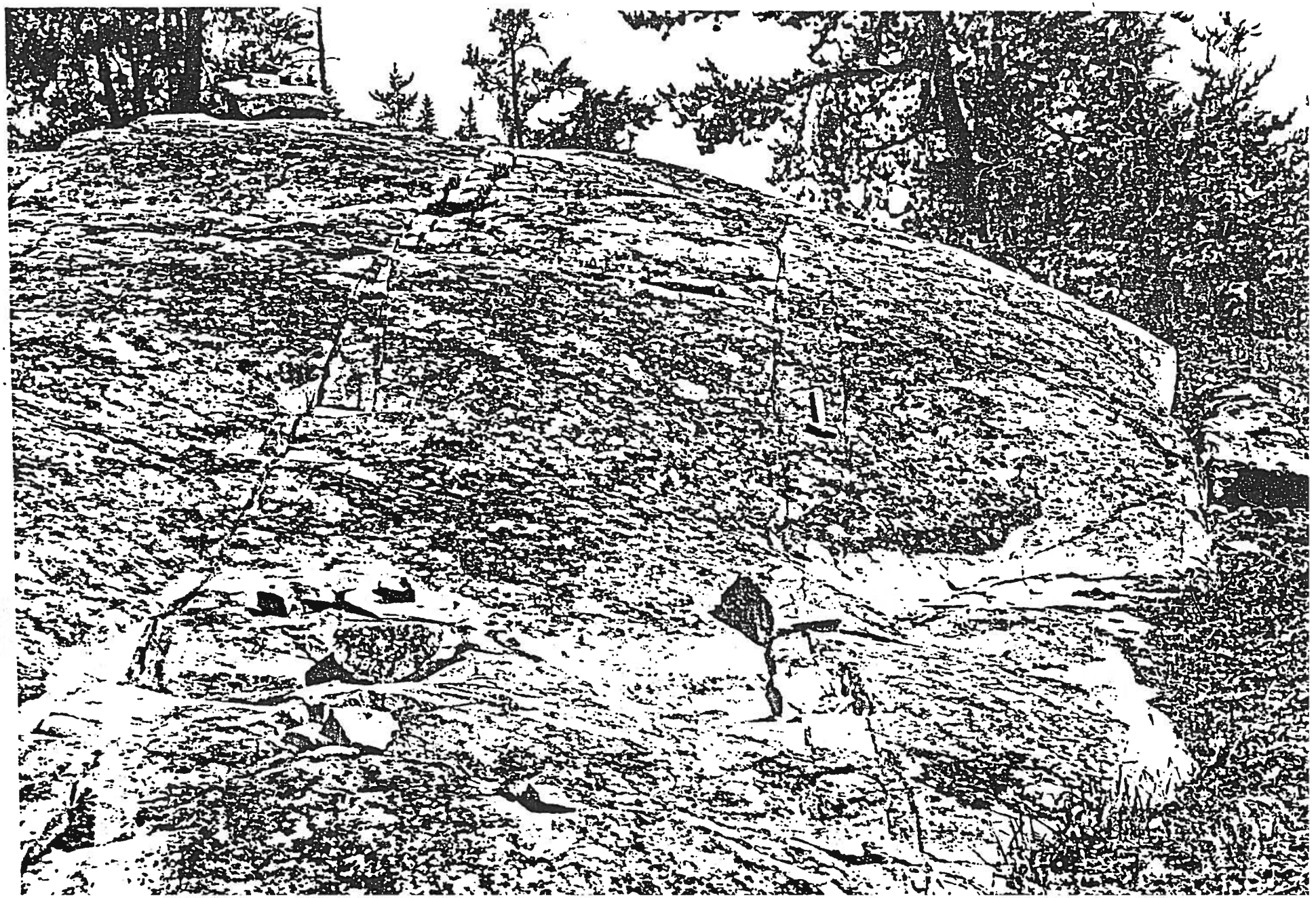
Photograph 29. Chipewyan Red Granite; widely spaced, poorly developed, vertical joints; one 2 foot wide zone of closely spaced bedding plane joints, otherwise widely spaced and poorly developed.



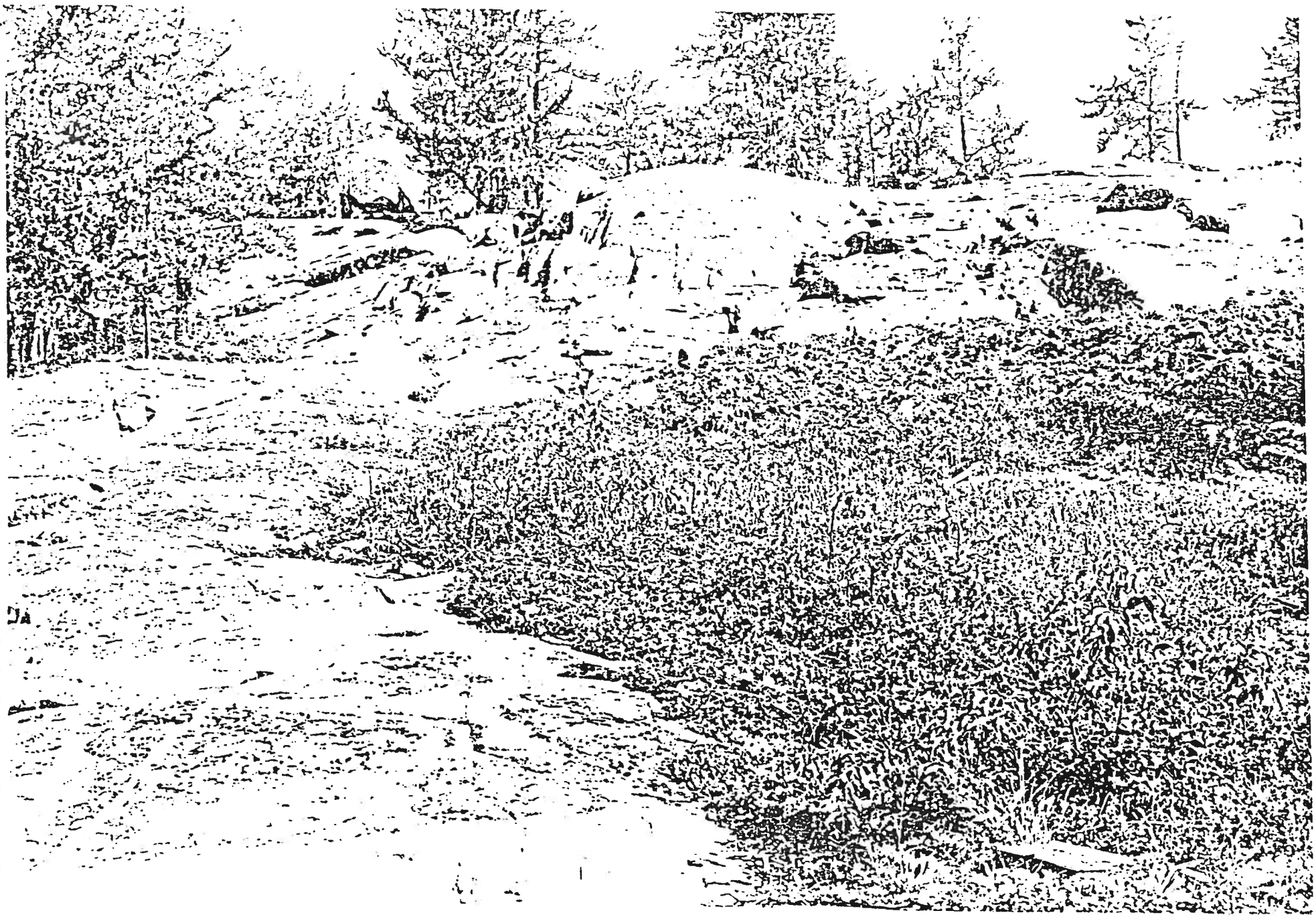
Photograph 30. Chipewyan Red Granite; one well developed vertical joint, otherwise poorly developed vertical and horizontal joints. Note orthogonal pattern (i.e. approximate right angles) of joint intersection and characteristic planar, single surface of fractures.



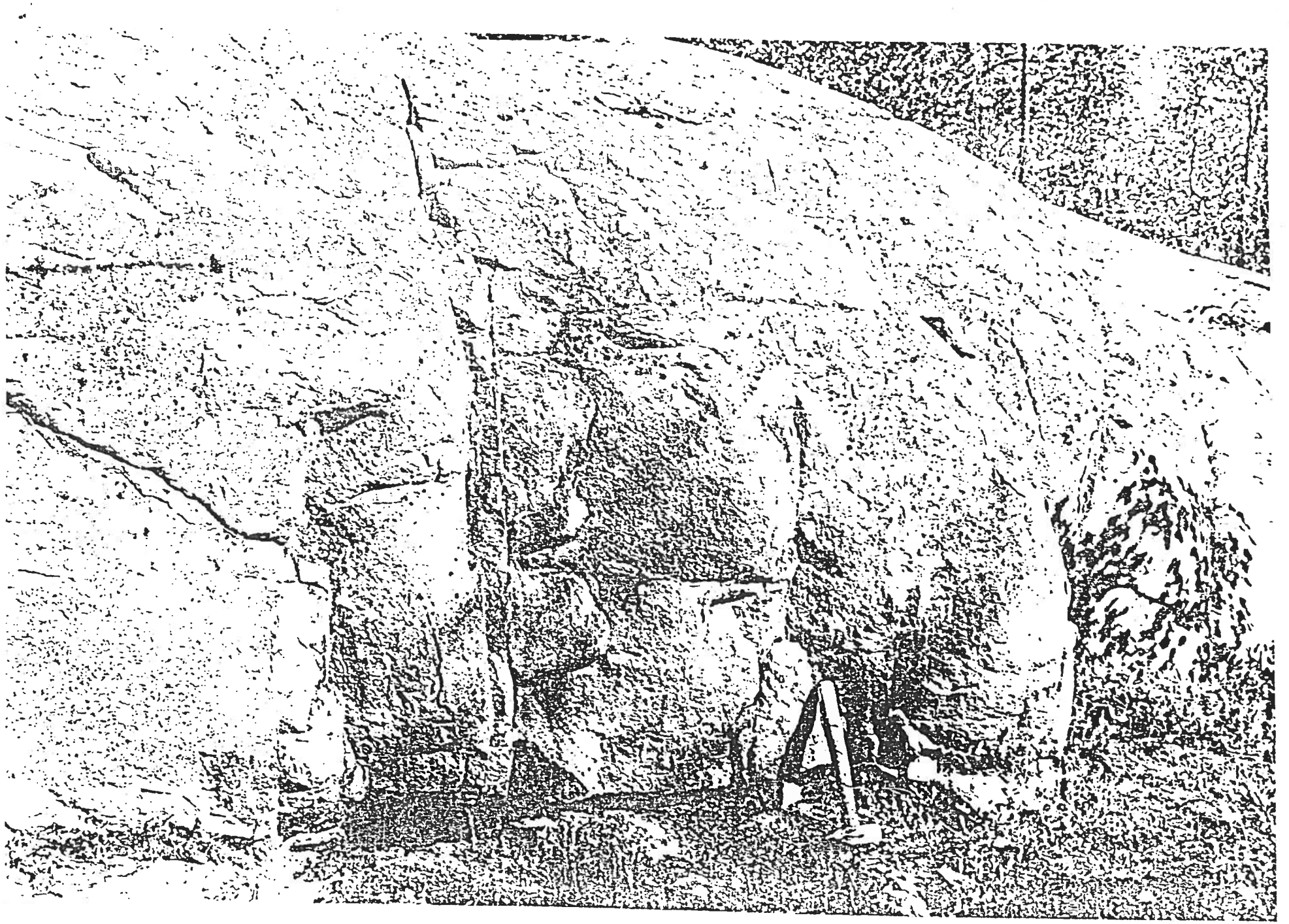
Photograph 32. Chipewyan Red Granite; widely spaced north-trending vertical joints; showing grouped parallel joints locally 'en echelon' in character.



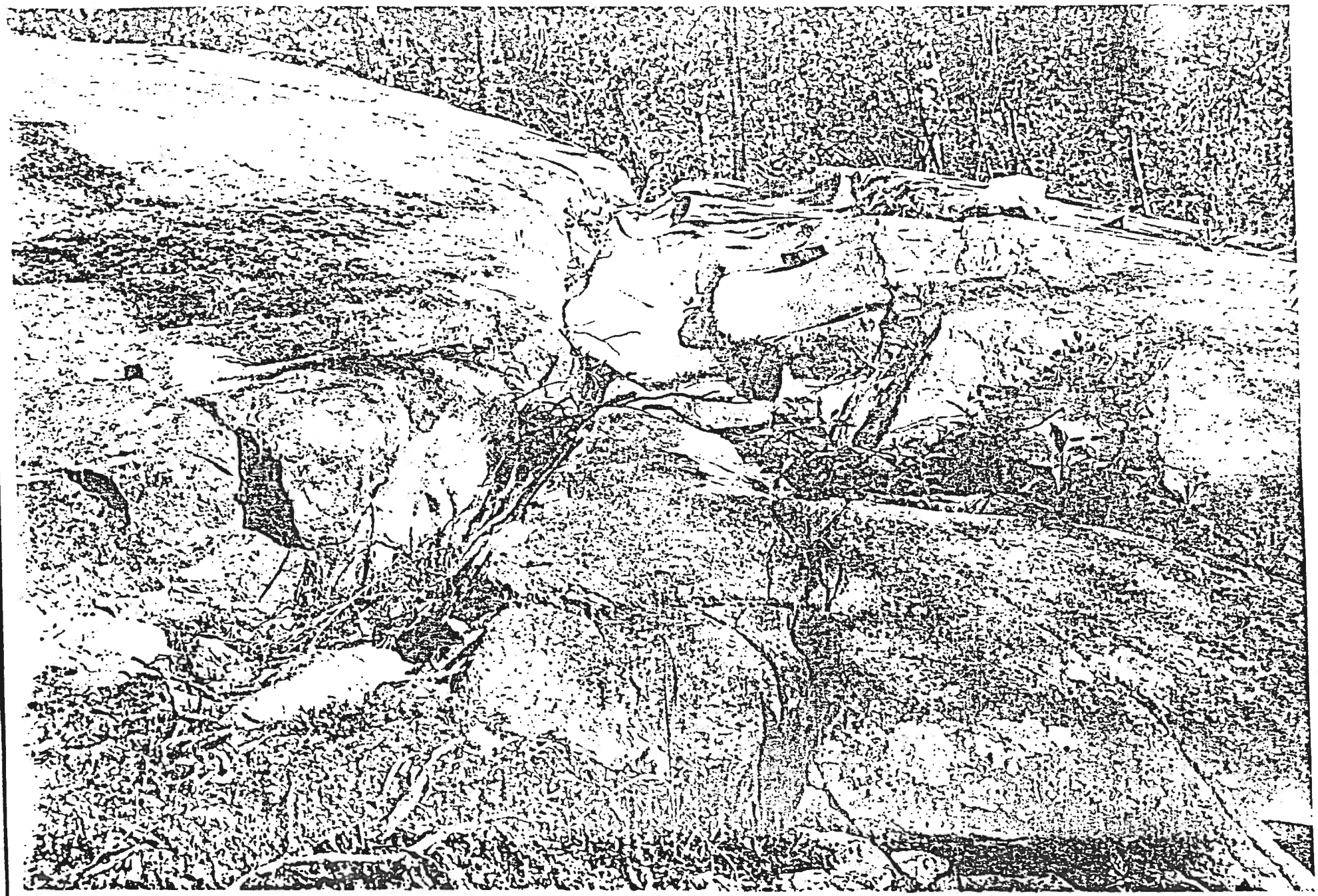
Photograph 33. Chipewyan Red Granite; general view looking north towards top of central section from extreme south end; showing painted base line.



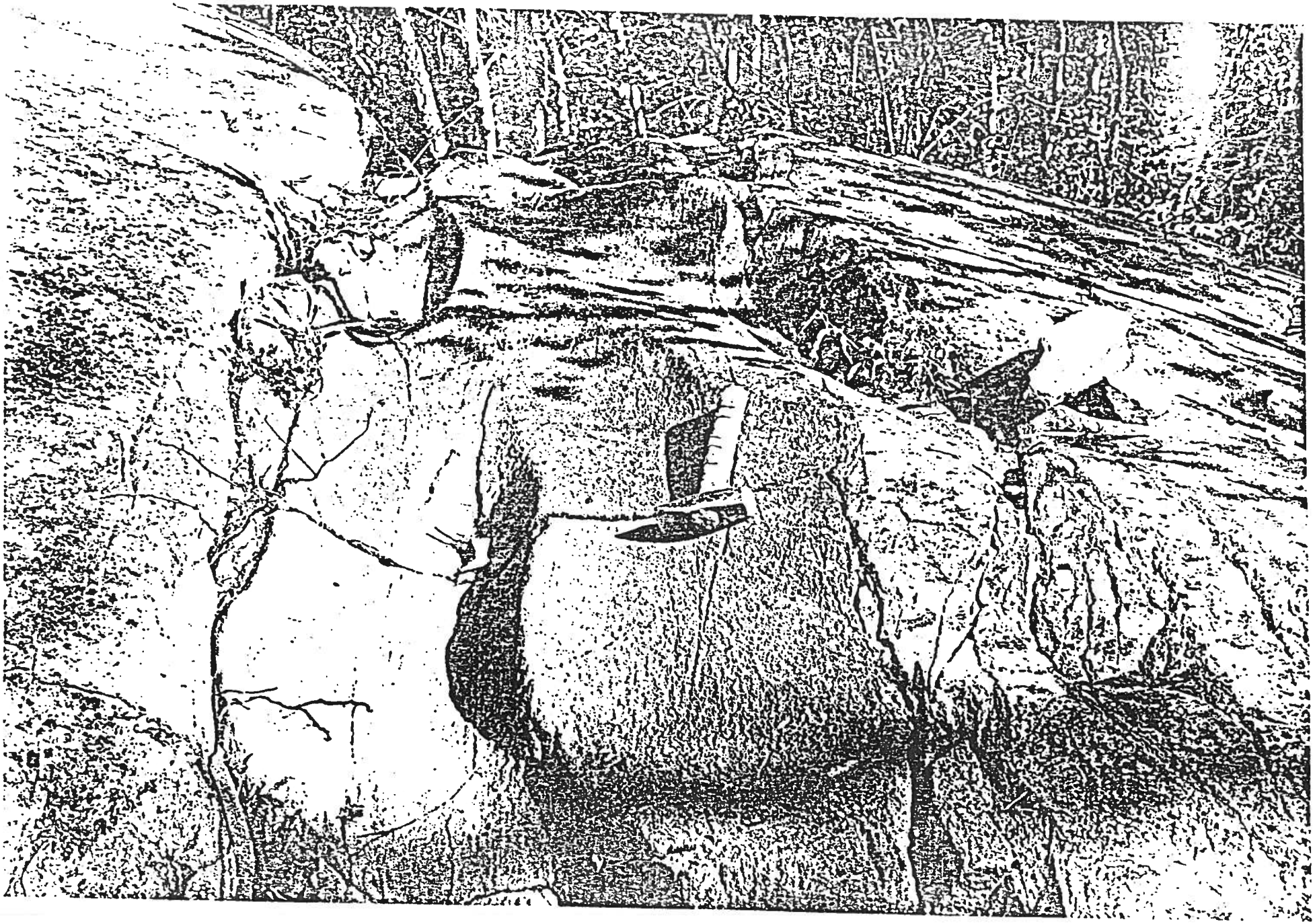
Photograph 34. Chipewyan Red Granite; widely spaced, poorly developed, vertical and bedding plane joints. Note orthogonal arrangement of joint surfaces.



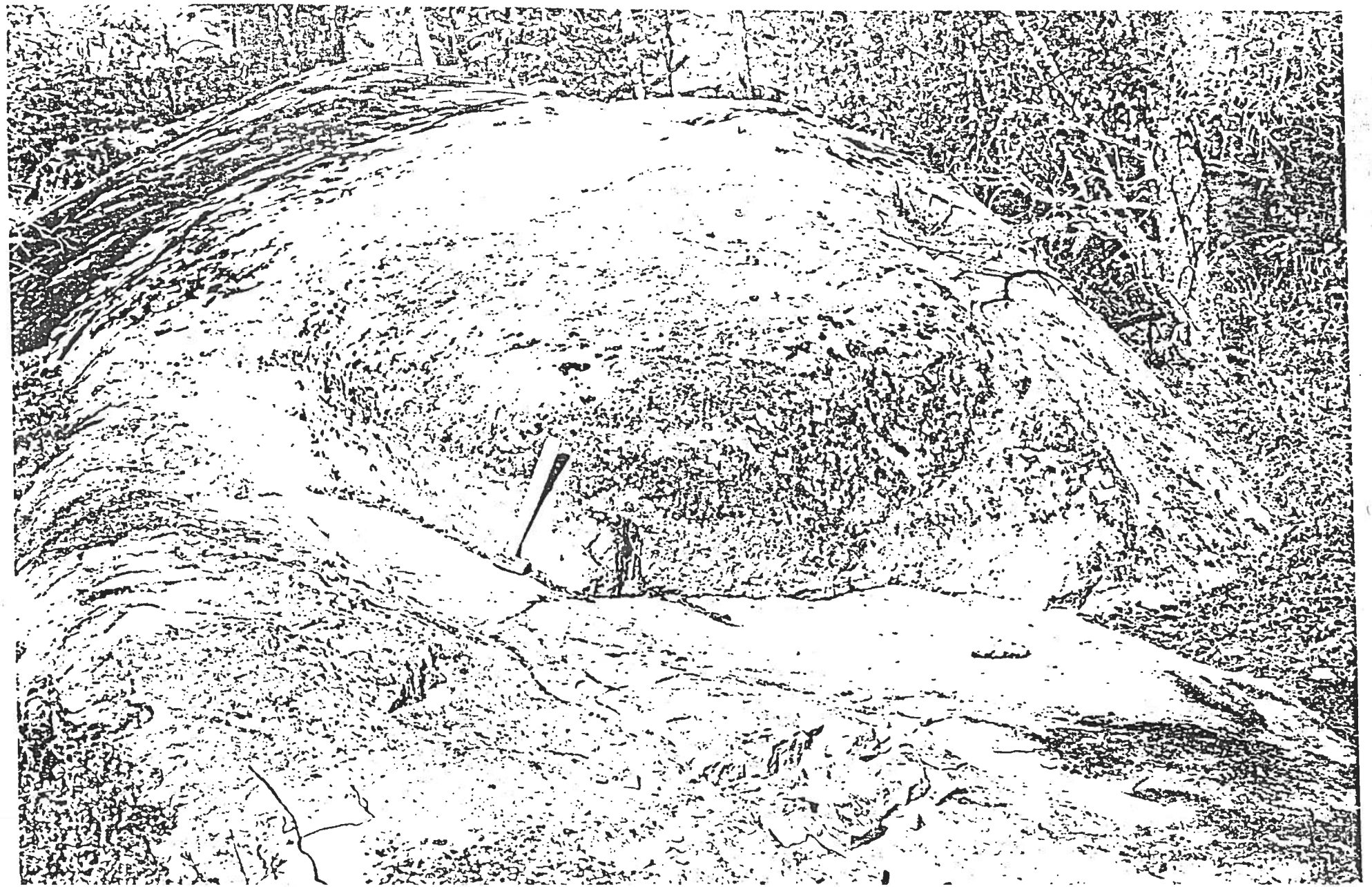
Photograph 35. Chipewyan Red Granite; two foot thick basic dyke (dark) intruding minor fault zone in east section.



Photograph 36. Chipewyan Red Granite; detail of two foot thick basic dyke (dark, beneath hammer) intruding fault zone within granite of east section.



Photograph 37. Chipewyan Red Granite; detail of a steeply dipping master joint trace.



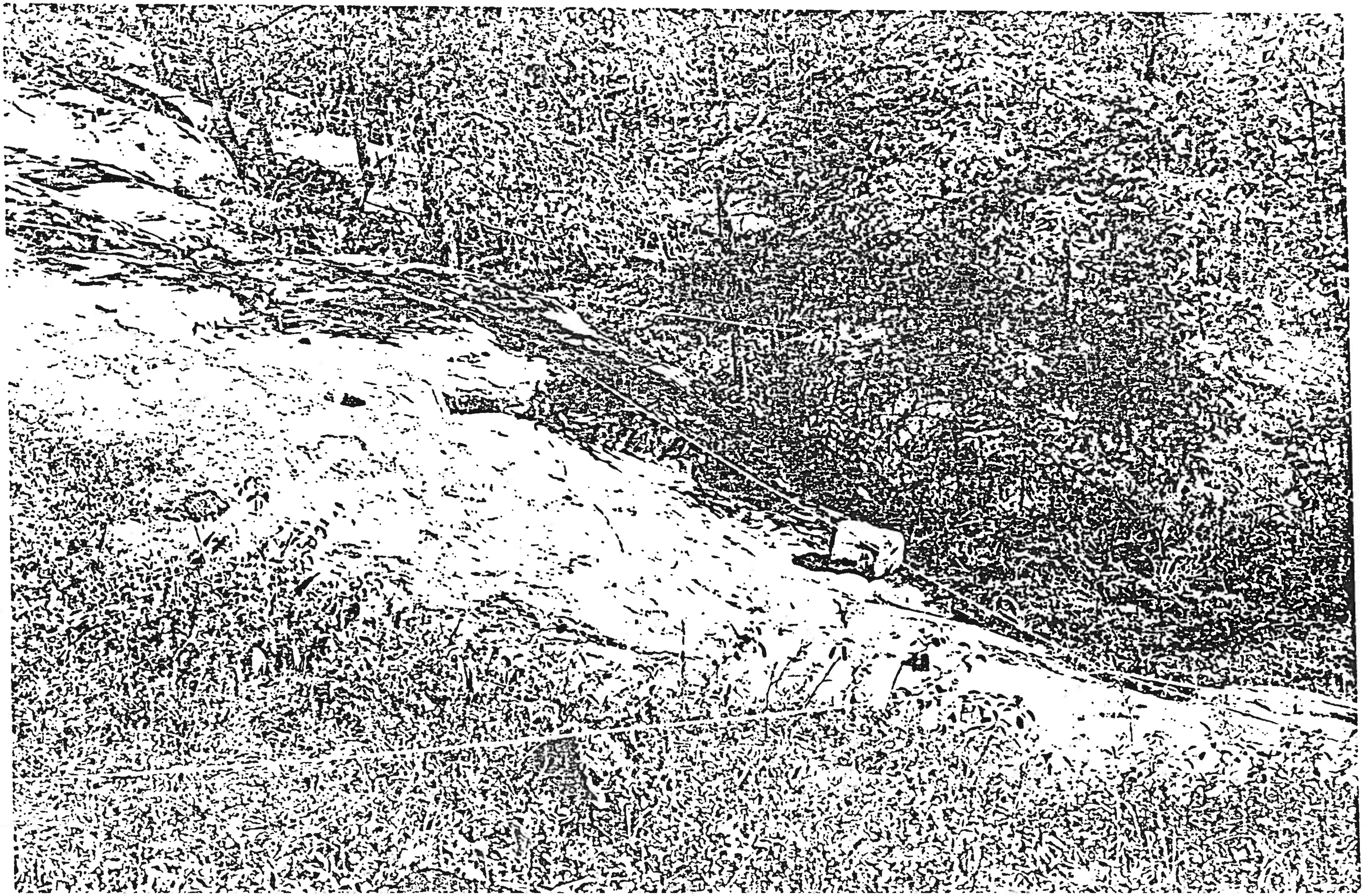
Photograph 38. Chipewyan Red Granite; widely spaced minor, major and master joints having a mutual orthogonal arrangement.

Photograph 39. Chipewyan Red Granite; narrow basic dyke intrusion along closely spaced multiple fractured, fault zone.

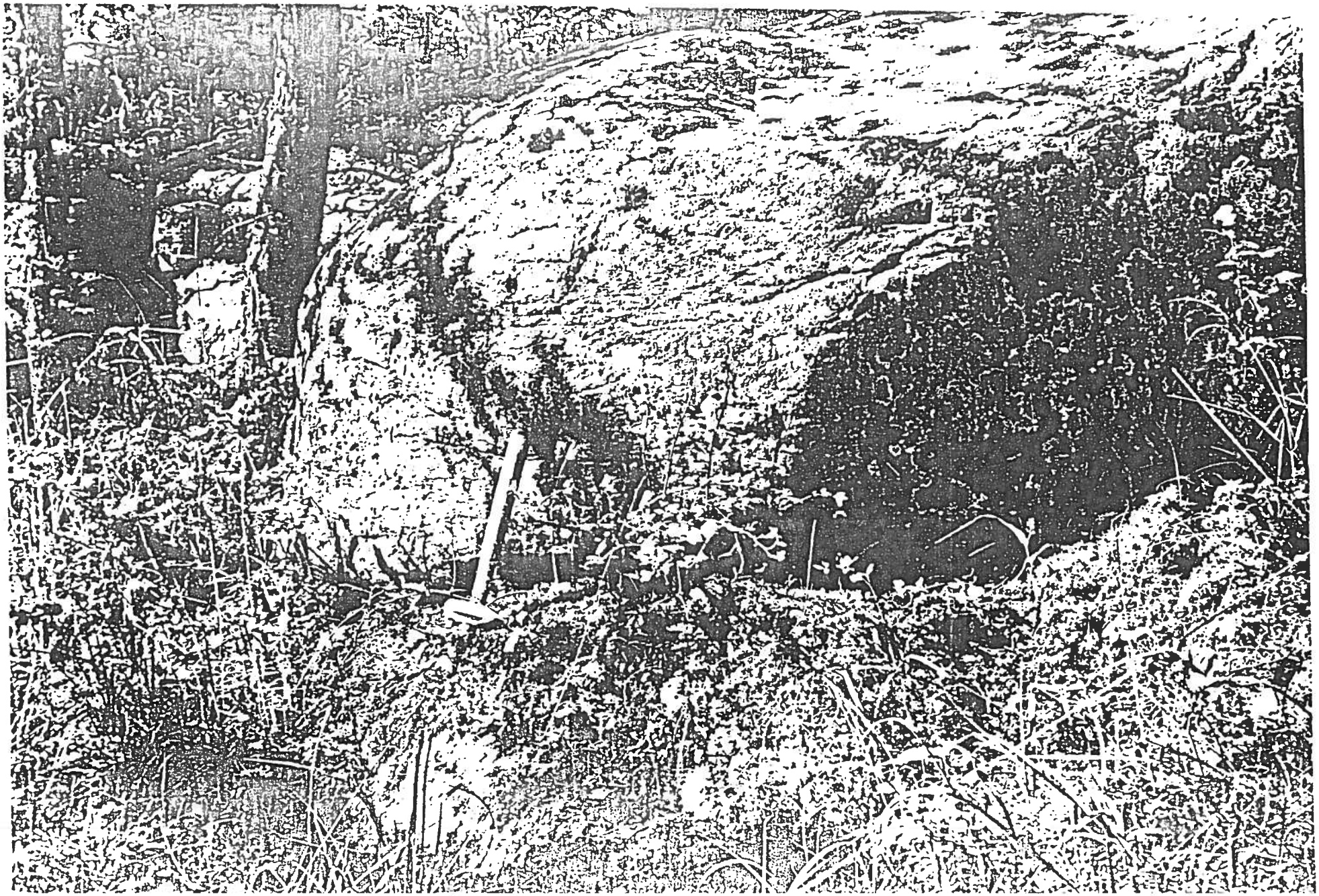
Photograph 40. Chipewyan Red Granite; major, north-trending master joint with unusual wide zone of multiple fracture surfaces.

Photograph 41. Chipewyan Red Granite; detail of a single-surface master joint intersected by minor bedding plane joints; showing portion of painted base line.

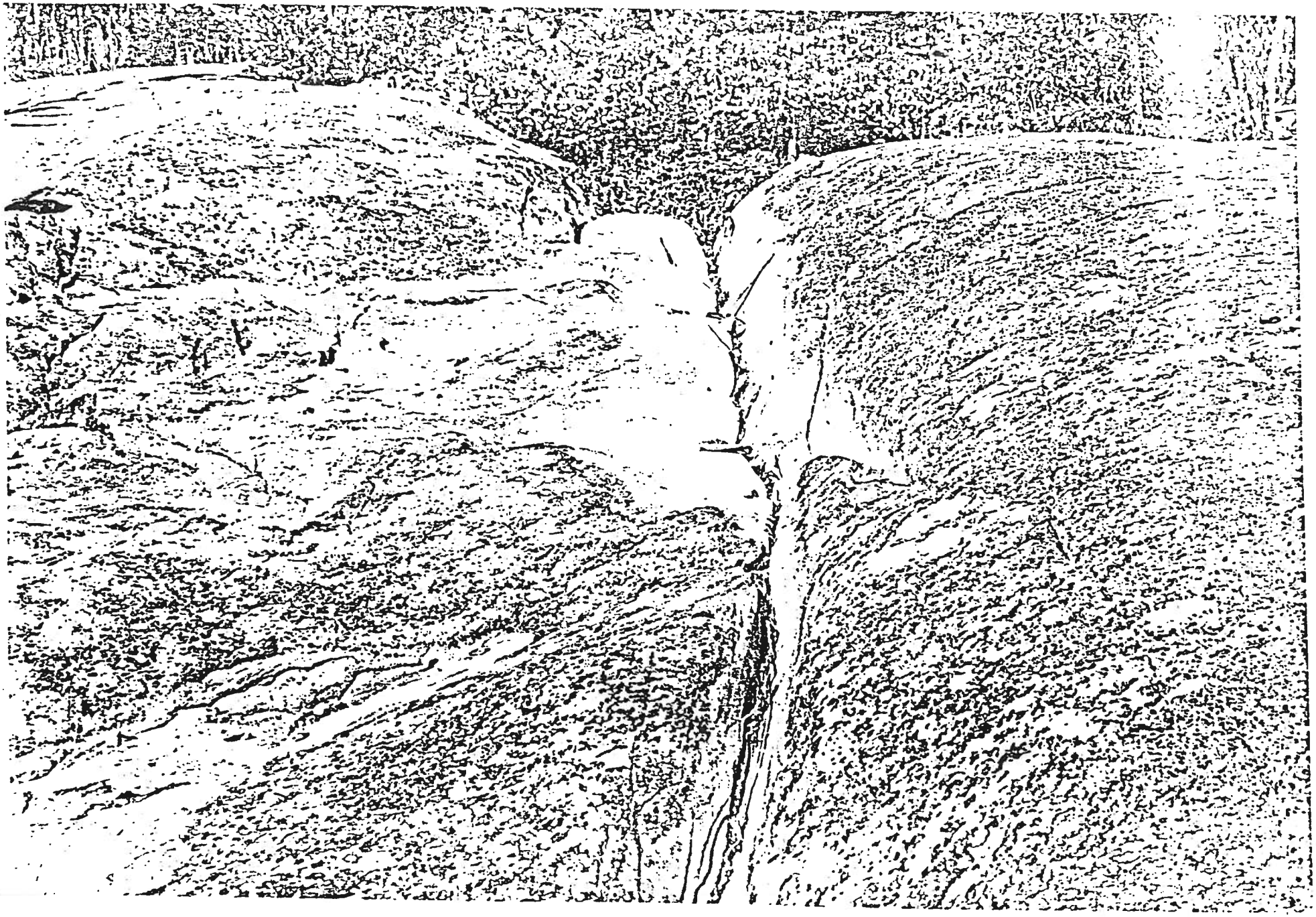
Photograph 42. Chipewyan Red Granite; for purposes of mapping the cleaned-off outcrop, 10 foot grid points were measured and painted on the outcrop. Strings were also placed between 20 foot grid points to form 20 foot squares.



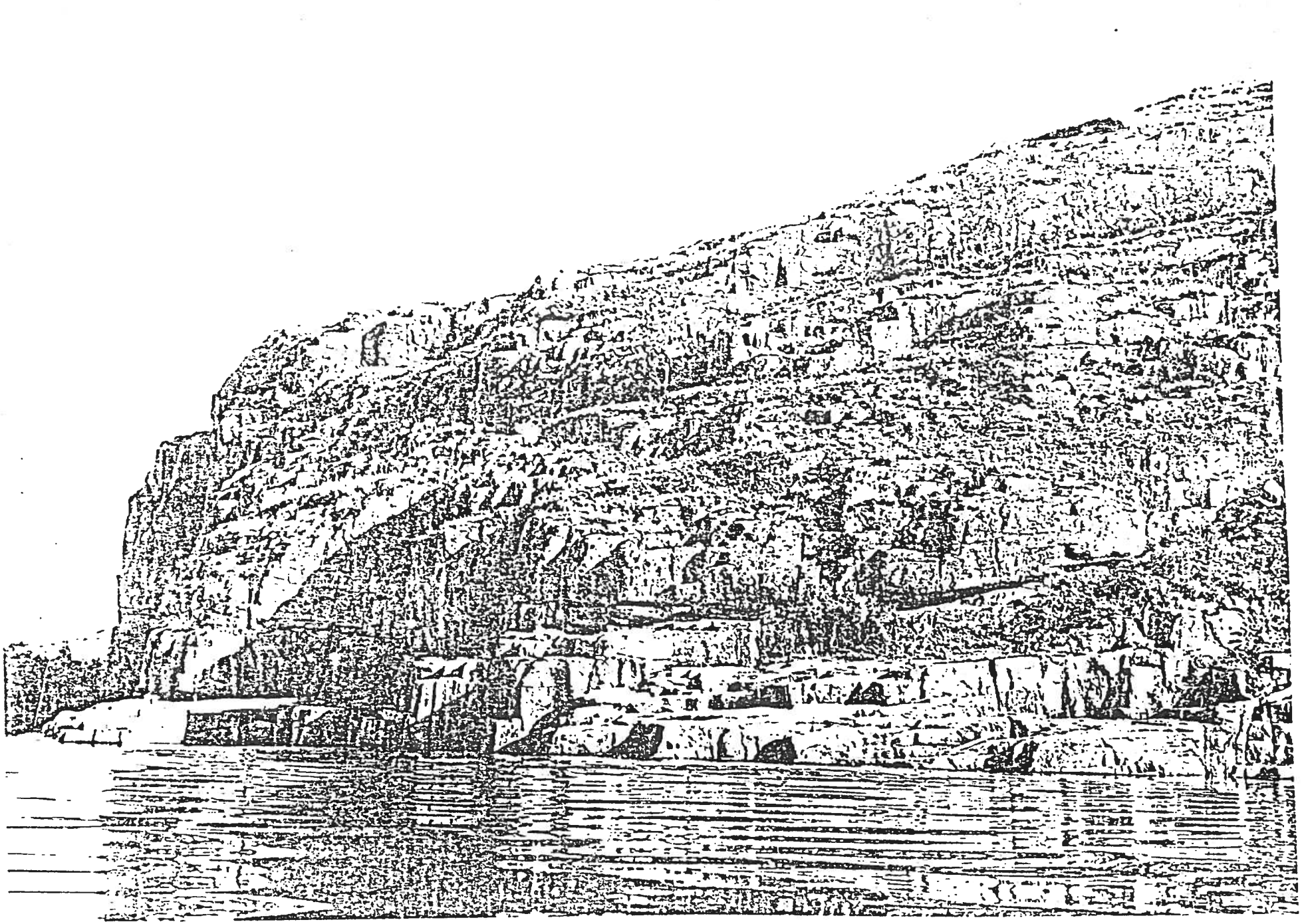
Photograph 43. Chipewyan Red Granite; showing the trace of poorly developed bedding plane joints at their intersection with vertical to steeply dipping joints.

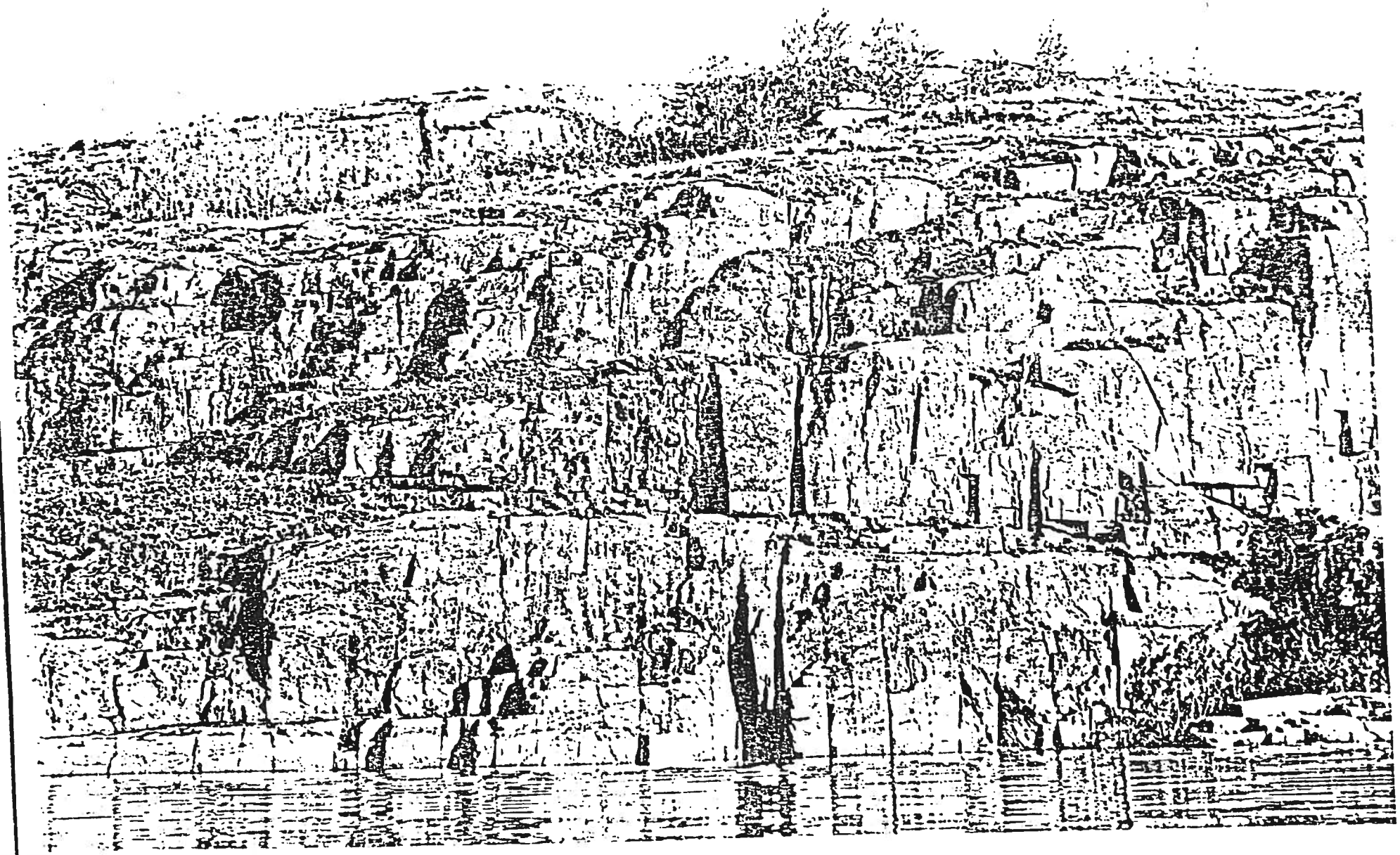


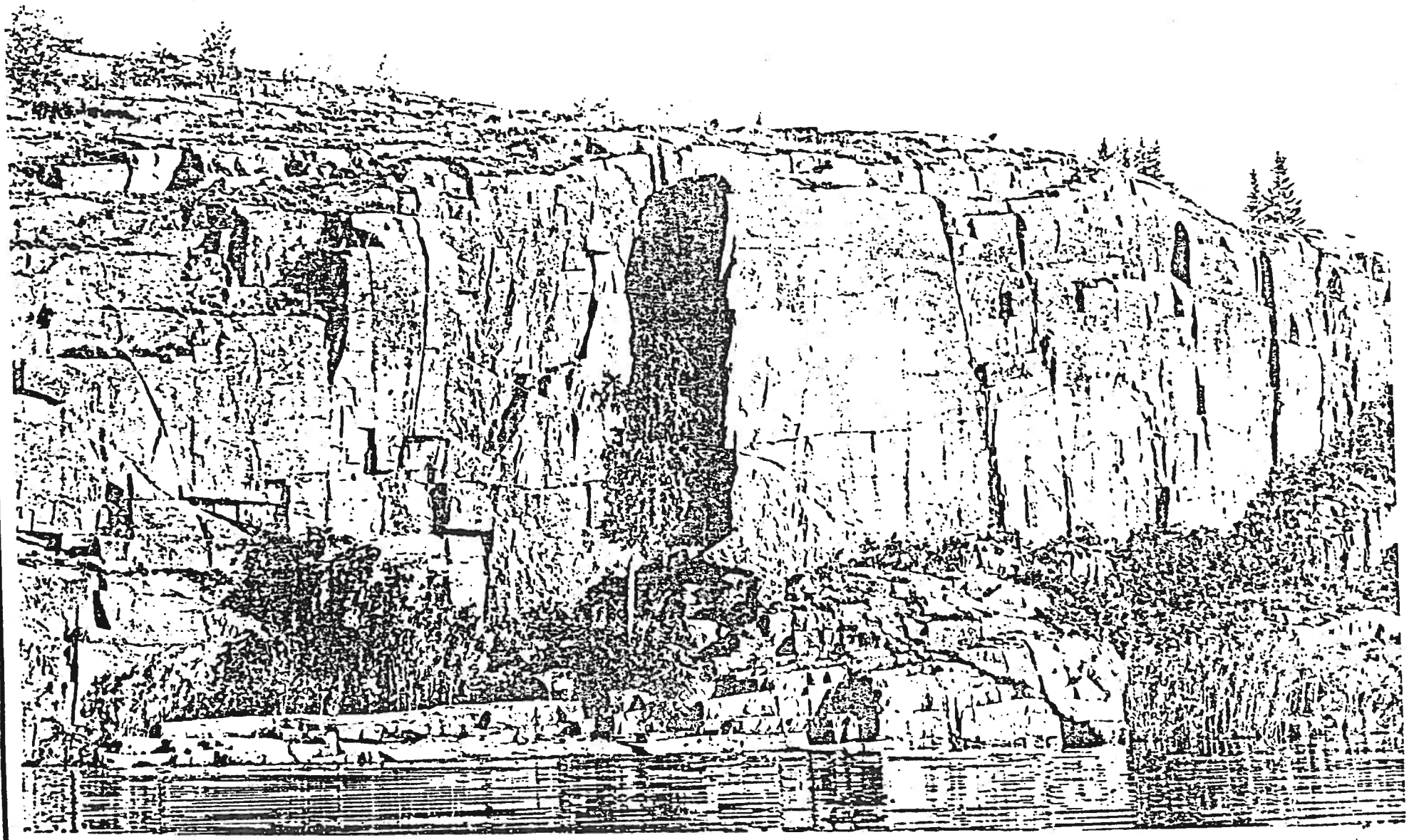
Photograph 44. Chipewyan Red Granite; glacial scouring has partly eroded and cleaned off a bedding plane joint in this small granite knoll.



Photographs 47, 48 and 49. Rivière des Rochers; three sets of well-developed joints (two vertical, one horizontal), on a high riverside bluff of granite gneiss adjacent to a fault parallel to the length of the bluff. Situated about 7 miles south from sluice site number two.







Photograph 31. Chipewyan Red Granite; unusual steep intersection of bedding plane joints with a well developed vertical joint. Dark stains on joint face are due to seepage and run-off from organic-filled depressions above.