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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1967/24

STABILITY OF THE CUT BOUNDING THE FORT HILL IRON ORE DUMP AREA. DARWIN. N.T.

by

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CONTENTS

SUMMARY

At the request of the Director, Mines Branch, a cut in the Fort Hill was investigated during the first week of November, 1966. The survey was made to determine the probable long-term stability of the cut. Rock slides and minor spalling are likely to occur, especially when the face is exposed during the wet.

Apart from giving the face an impermeable capping, little else can be done about these potential slides.

The backfilling of an exposed tunnel is recommended.

INTRODUCTION

In preparation for the export of iron-ore from Darwin Port, over an eight year period, a thirty to forty-five foot high slope was cut into Fort Hill to act as a retaining wall for an ore stockpile (see Plate 1).

To date, there has been one rock-fall, probably due to the partial collapse of a tunnel, and one translational rock-slide. Minor spalling has also occurred. All falls were controlled by planes-of-weakness.

GEOLOGY

"The western part of the hill consists of shale of the Noltenius Formation and the eastern half of sandy shale and impure sandstone. The hill is capped by Mullaman Beds" (Gardner & Rix, 1963/57, p.9).

Noltenius Formation

The present face consists of a highly weathered, weak, closely cleaved and fractured, sericite phyllite ("shale").

Weathered phyllite absorbs water readily, tending to slough and form a sericite-silt with low to zero cohesion (0-6 pounds per square inch from shear strength tests by Department of Works, Melbourne).

Fractures

As there are a number of important fracture sets, they have been designated A, B, C, etc.

Cleavage planes (A fractures) strike 007°-022° magnetic and dip 86°-90°E. The fractures are spaced ¼"-2" apart and many can be traced over the full height of the face. Along cleavage planes the rock ranges from iron-stained to highly weathered and weak.

Five major B fractures traverse the full height of the face (Plate 2). They strike between 092°-105° and dip 17°-26°S. Up to one inch of rock on either side of the fracture planes has been leached to a white, weak, unctuous, sericitic silt.

The major C fracture set strikes 162°-178° and dips 40°-72°E with a fracture spacing of between 3 inches and 3 feet. The fractures are generally tight with inconspicuous surface traces. As they cut across the cleavage, most surfaces are rough and many are stained by limonite. Some fractures have a silt infilling. This set is associated with slides of small blocks of rock.

The D fracture sets strike 072°-087° and dip 35°-43°S, 62°-68°S, and 85°-90°N and S. The shallow dipping set has up to one inch of clay infilling, the other two sets cut obliquely across the cleavage and are normally inconspicuous, rough and iron-stained. The whole group is associated with minor block slides.

An intermediate E set strikes 110°-140° and dips 82°-88°S. These fractures are inconspicuous, rough, iron-stained and associated with minor falls of rock.

Other minor fractures are also present, with various orientations.

Mullaman Beds

Overlying the Noltenius Formation is a 15-35 foot hard-cap of Cretaceous Mullaman Beds. These beds are massively jointed and partly lateritised; they are of porcellanite and sandstone, with a thin basal quartz-pebble conglomerate.

SLOPE STABILITY

Observations

The Mullaman Beds were almost completely removed by stripping to a reduced level of 62-76 feet before the main cut was started. The cut was completed in March-April 1966, producing a 30-45 foot face trending 017°-025° and with an overall batter of 52°-60° and a small basal slope of 33° (Plate 3).

On May 9th, 1966 a 350 cubic-yard rock-fall (volumes quoted are only approximate) occurred above a tunnel (personal communication from N. Hanson, Engineer-in-Charge). The tunnel is one of a number driven through Fort Hill during the Second World War. The tunnels are unlined and have only timber supports, which have probably decayed by now. The collapse of the exposed part of the tunnel may have been triggered by rainfall on May 4th (The Meteorological Office recorded falls of from 15 to 50 points in the Darwin area).

The fall is cut-off to the south-west by a C fracture (168°/50°E) filled with weak, highly weathered phyllite.

An E fracture (140°/86°S), coated with weak, sericitic silt limits the fall to the north.

The back face is formed by a cleavage plane (022°/90°) and a minor fracture (034°/62°E). The latter is coated with half an inch of white sericitic silt.

A 40 cubic-yard rock-slide also occurred 140 feet from the southern end of the face (Plate 2); the date of the slide is not known. The slide extended from the top of the cut down to a point 15-20 feet below the top; its lower limit was determined by a major B fracture (092°/17°-26°S). This fracture has a one inch coating of weak, weathered, sericitic clay.

A clean, rough, C fracture cuts the slide off to the south. The upper part of this fracture has a sericitic-silt infilling. On the northern side, a clean E fracture confines the slide, which extends 4 to 5 feet back into the face. The back of the slide is bounded by a cleavage plane.

Owing to the oblique orientation of the cleavage in relation to the face, minor slabbing occurs. Facial dimensions of the plates are determined by the fracture sets; normally, the plates are less than two cubic feet in volume.

Blocks up to one cubic feet in volume also slide out of the face from time to time. These blocks are normally bounded by C and D or E fractures.

Discussion

The shear resistance (τ) against movement of a block depends on the cohesive bond (So) between adjacent faces, and the effective angle of sliding friction (ϕs).

$$\text{i.e. } \tau = So + \tan \phi S$$

If the cohesive bond is zero, τ is the controlling factor.

Owing to the orientation of the face with respect to the fractures, further slides will probably occur. If cohesion is zero, movement will occur where the trace of intersecting fractures, bounding a block, dips out of the face at an angle greater than the angle of sliding friction for the material.

No ϕs values have been determined for the phyllite, but the following points are relevant.

(a) The phyllite is extremely sericitic

(b) The sericite flakes tend to be oriented parallel to the cleavage

(c) Horn & Deere (1962), in a series of laboratory tests on the sliding friction of minerals, determined the following sliding-friction values for muscovite (a white mica similar to sericite).

	Wet ϕs	Dry ϕs
single flake muscovite	12°-15°	22°-24°
ground muscovite	16°	

(ground muscovite is equivalent to a mica soil).

(d) The trace of intersection between the two fractures which have controlled the movement direction of past rock slides strikes 136° and dips between 10°-18°SE, out of the face.

From the above points, the ϕ value for sericitic-silt filled fractures is probably in the order of 20°-25° when dry, less when wet (possibly 16°). Hence, if cohesion between fracture faces is weakened by weathering, rock slides are liable to occur on planes with apparent dips out of the face, as low as 16°-20°. The most likely sites for these are along the major B fractures.

Since the weathered phyllite tends to ravel when dry and be washed away when wet, there will be minor under-cutting of the exposed face. This under-cutting will allow minor block slides, up to 15 cubic feet in volume, to occur intermittently over a long period of time.

Once the ore stack has reached its designed height of 62' (min.) 79' (max.) (see Plate 3) the only danger of rock slides will occur when the pile is drawn down, especially during and after heavy rain.

When the ore stack is at its maximum height there is danger of further collapse of the tunnel due to the overlying weight of iron ore. Hence, when the existing fall debris is cleaned up around the tunnel, attempts should be made to back-fill the tunnel as much as possible and the portal should be supported by steel or wooden sets. In addition, the "wings" on either side of the fall should be trimmed.

CONCLUSIONS AND RECOMMENDATIONS

1. Further rock slides, involving up to 50 cubic yards of rock, will probably occur, especially following heavy rain. The critical period for these is prior to filling the ore stack and during periods of draw-down. The most likely area for these to occur is the southern part of the face, above No. 1 B fracture.

Little can be done to prevent potential slides. Reducing the batter will reduce the gravity sliding component. However, if cohesion between fracture planes is low, reducing the batter will not greatly affect the stability of any potential slide owing to the low angle of sliding friction.

Since cohesion is the controlling factor, it is important that weathering and progressive failure along fractures and lubrication of fracture infillings, is not encouraged. Water should be prevented from penetrating the steeply dipping fractures and small tension cracks present at the top of the face. Hence the cut should be given an impermeable capping with drainage away from the face.

2. Small block slides and spalling will occur when the face is not protected, especially during the wet season. Most blocks will probably be in the size range, 1 cubic foot to 20 cubic feet. The southern part of the face is likely to collapse progressively in this manner. In addition, broken scree material near the top will wash down.

3. The entrance to the tunnel should be supported to prevent further collapse.

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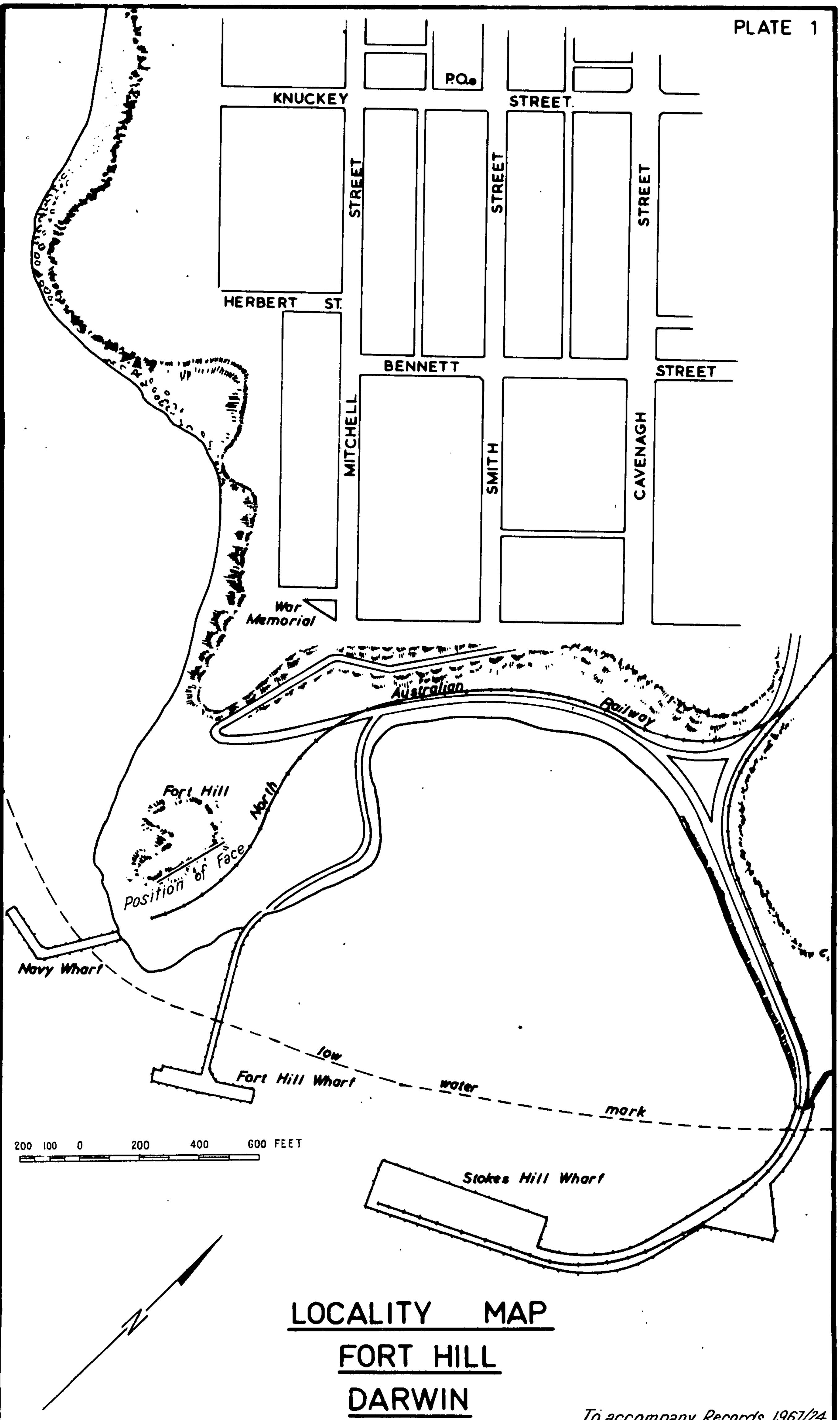
PLATE 1



LOCALITY MAP
FORT HILL
DARWIN
NORTHERN TERRITORY

To accompany Records 1967/24

COMPILED BY RESIDENT GEOLOGICAL SECTION
DRAWN BY MINES BRANCH DRAUGHTING OFFICE DARWIN JAN' 1967

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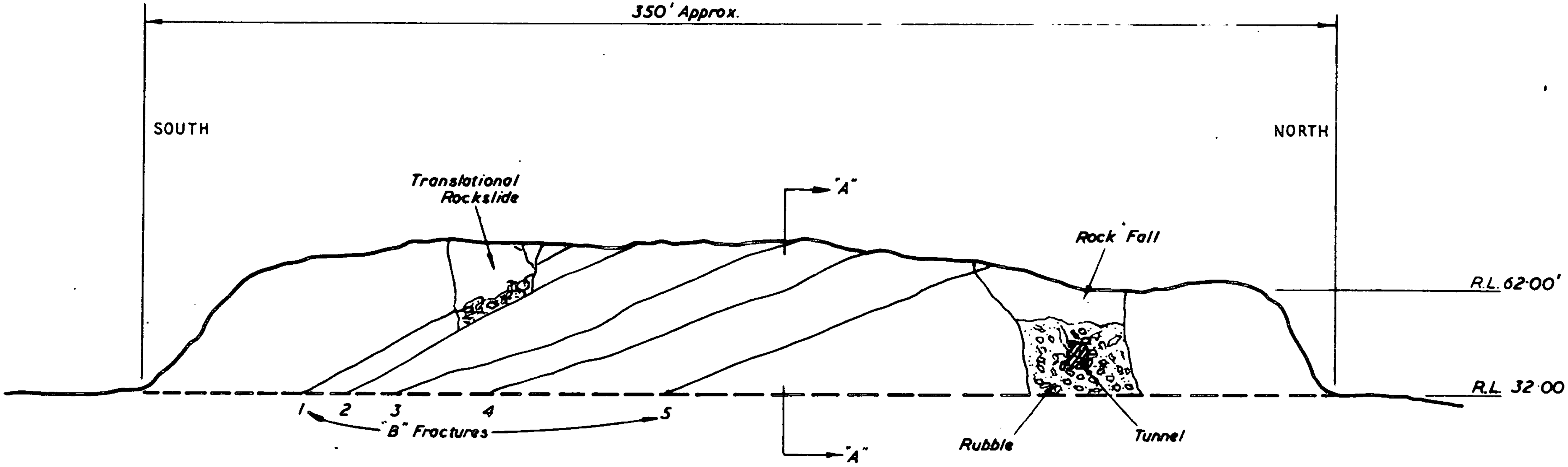


EXISTING FACE (SHOWING POSITION OF ROCK FALLS)

FORT HILL

DARWIN

NORTHERN TERRITORY

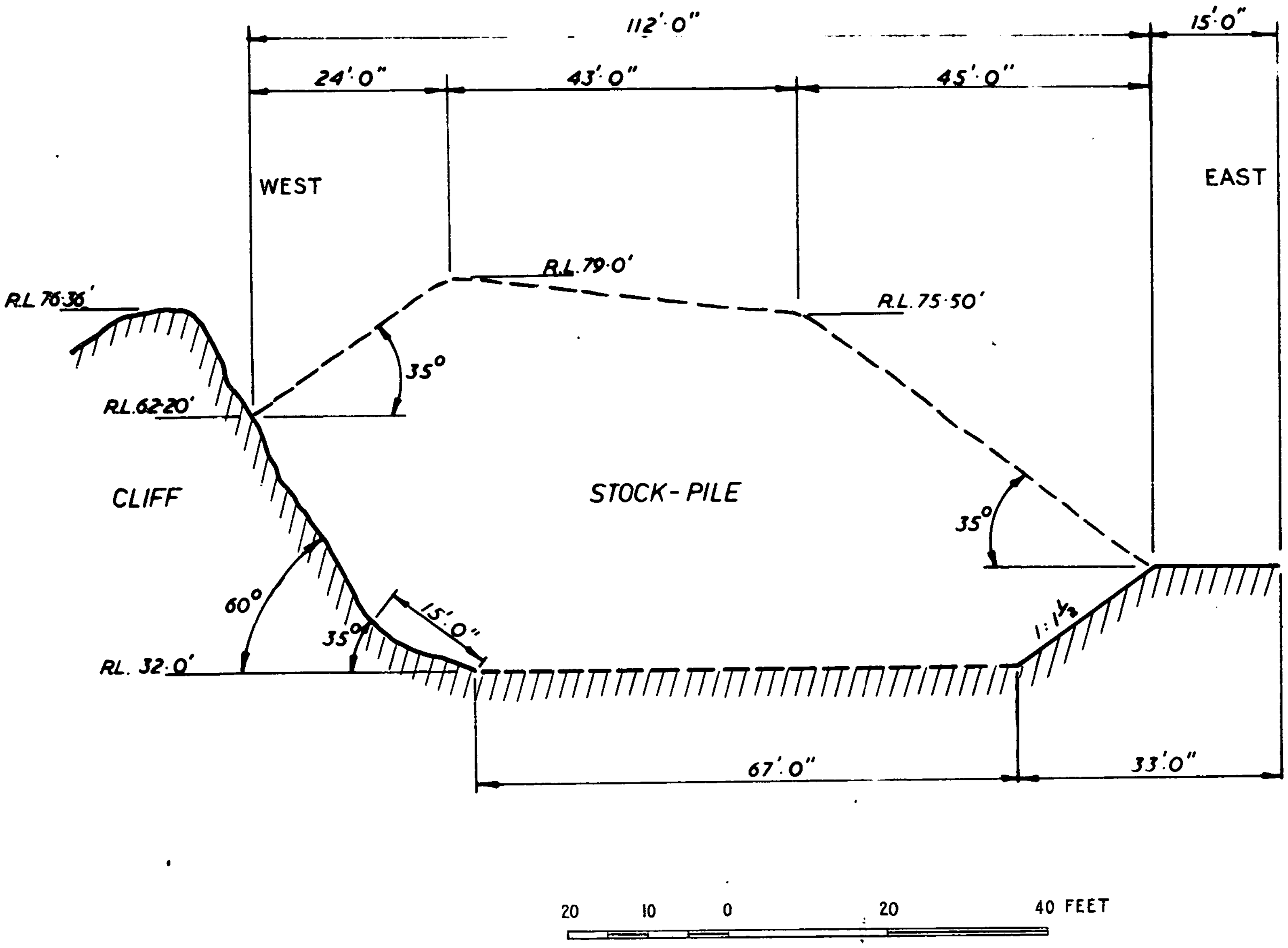
20 10 0 20 40 60 FEET

To accompany Records 1967/24

PLATE 2

COMPILED BY RESIDENT GEOLOGICAL SECTION
DRAWN BY MINES BRANCH DRAUGHTING OFFICE DARWIN JAN' 1967

G67/4E



SECTION 'AA' (See Plate 2)

CLIFF FACE & STOCK - PILE

FORT HILL

DARWIN

NORTHERN TERRITORY

To accompany Records 1967/24

PLATE 3

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