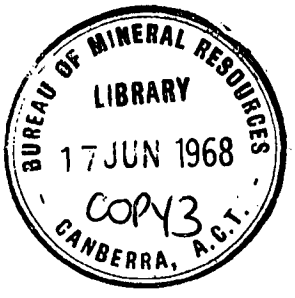
COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS

RECORDS:

RECORD NO. 1968/14



CARPENTARIA REGION
UPPER MANTLE PROJECT 1966.
OPERATIONAL REPORT

by

D.M. FINLAYSON

5928/65

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SUMMARY

The Carpentaria Region Upper Mantle Project (CRUMP) was a large-scale seismic refraction experiment carried out in north-east Queensland between 20th September and 6th October 1966. The Royal Australian Navy exploded fourteen charges on the sea bed at predetermined positions on the continental shelf. Altogether seventeen mobile and seven fixed seismic recording stations attempted to record the resultant seismic waves.

Only the operational aspects of the experiment are described. The results and consequent analysis and interpretation in terms of crustal structure will be presented separately.

1. INTRODUCTION

At a meeting in Canberra on 2nd May 1966 the Royal Australian Navy stated that it was prepared to participate in two Bureau of Mineral Resources seismic projects involving the detonation of charges on the sea bed off the coasts of Queensland and Western Australia. This report is concerned with the project in the north Queensland area, the Carpentaria Region Upper Mantle Project (CRUMP). The project was designed to measure crustal and upper-mantle velocities, and depths to the M-discontinuity, across a number of lines of seismic recording stations in the north Queensland, Torres Strait, and Gulf of Papua region. A number of east-west lines were considered so that it would be possible to obtain records from shots fired both to the east and to the west of the Cape York Peninsula. A number of north-south lines were considered but only in a few cases was it possible to record shots from two opposing directions. The east-west lines traversed the mountains of the Great Dividing Range where it might be possible to detect variations in the crustal thickness.

The shots in the Gulf of Carpentaria were to be used by the Australian National University (ANU) to calibrate their large seismic array at Warramunga, and for this purpose ANU fielded three portable recording stations in Northern Territory and north-west Queensland. Shots fired in the Torres Strait were designed to obtain velocities along a north-south line in Cape York Peninsula continuing to Daru on the north side of the Strait, and along a east-west line across the Gulf of Papua to sites near Port Moresby. The recording lines finally chosen are shown in Plate 2.

2. PARTICPANTS AND CO-OPERATING ORGANISATIONS

H.M.A.S. KIMBLA operations

The shots for CRUMP were fired from H.M.A.S. KIMBLA en route to Darwin from Sydney. A copy of the R.A.N. Trial Instruction 2/66 is given in Appendix 1, which includes the firing programme proposed shortly before H.M.A.S. KIMBLA sailed from Sydney. The procedures to be carried out on board H.M.A.S. KIMBLA for the handling and lowering of charges are summarised later in this section.

Appendix 2 gives a summary of the ship's firing programme as obtained from notes kept by seismic recording crews and by the BMR officer on board the ship.

The explosives used consisted of Second World War depth charges each weighing about 500 lb, but only 300 lb of this was explosive material. Four of these were strapped to a pallet to make up a 'one-ton' charge. The charge was fused and a light firing line was attached before the pallet plus charge was lowered over the side of the ship on a steel cable. When the charge was on the sea bottom, the steel cable was disconnected from the ship and attached to a buoy. The ship then steamed off to a safe distance, paying out light firing cable as it went. The charge was fired and the steel cable retrieved.

The comparatively large number of misfires suggests that some improvement in the method of firing would be desirable. The cause of most of the misfires was some fault in the telephone cable used as firing line. The method of lowering the pallet containing the charge seems to be successful because the charge can be retrieved very easily if necessary and the firing line is not required to carry a load. However, the firing line was only light plastic flex and was easily damaged during the ship's manoeuvres. Damage to the firing line might have been reduced if a floating cable had been used, or if a number of floats had been attached to the firing line so that it would not sink under the ship.

As a result of shot 16 being fired half-an-hour before the announced time, a number of seismic stations did not record the shot and this considerably reduced its value.

During shots 15 and 16 the quality of the ship's transmitted signals was very poor owing to a fault in the shipborne equipment.

It is clear from the results of CRUMP operations that, in future, more time should be allowed for the ship to get into position and lay the charge and to allow for unforeseen events.

Organisations providing seismic recording crews

The Officer (Scientific) in Charge of the project was J.C. Dooley of the Bureau of Mineral Recources, Geology and Geophysics (BMR). The officer responsible in the field for liaison between various recording organisations and for instructing the R.A.N. during the actual field operations was D.M. Finlayson of the BMR.

Table 1 gives details of the equipment and tools used by the various recording crews and the organisations responsible for the logistics and personnel.

TABLE 1

Recording crew personnel and equipment

Organisation	Radio equipment	Timing	Geophones or Seismometers	Recording
BMR No. 1 (P.Mann)	Traeger transceiver and A.W.A. Radiola receiver.	Internal-timing from 10-Kc/s oscillator. Absolute timing from VNG.	4-c/s geophones. 22-channel spread. 4 geophones per channel.	24-channel S.I.E. recorder. Recording speed 110 mm/s. One channel used

Organisation	Radio equipment	Timing	Geophones or Seismometers	Recording
		Relative timing from ship's broadcast.		for VNG timing and another for ship's broadcast.
BMR No. 2 (J. Grace)	Traeger transceiver	Internal timing from 10-Kc/s oscillator. Relative timing from ship's broadcast.	4-c/s geophones. 23-channel spread. 4 geophones per channel	24-channel S.I.E. Recording speed 110 mm/s. One channel used for either VNG or ship's broadcast.
BMR No. 3 (D. Finlayson)	1 AWA portable receiver 2 National receivers	Relative timing from ship's broadcast. Absolute timing from VNG. Chronometer timing from Mercer chronometer with 1-min pips.	1 Willmore Mk2 seismometer, nominal period 1 second.	Willmore recorder. $\frac{1}{4}$-sec galvo. Recording speed 240 mm/min.
BMR No. 4 (I. Everingham)	Traeger transceiver AWA Radiola receiver.	Relative timing from ship's broadcast. Absolute timing from VNG. Chronometer timing from Mercer Chronometer, one-min pips.	1 Willmore Mk2 seismometer, nominal period 1 second.	Willmore recorder. $\frac{1}{4}$-sec galvo. Recording speed 240 mm/min

Organisation	Radio equipment	Timing	Geophones or Seismometers	Recording
BMR No. 5 (R. Sutton)	Traeger transceiver AWA Radiola receiver	Relative timing from ship's broadcasts. Absolute timing from VNG.	1 Willmore Mk1 seismometer, nominal period 1 second.	Willmore recorder. ¼-sec galvo. Recording speed 80 mm/min
BMR No. 6 (R. Cooke)	Traeger transceiver AWA Radiola receiver	Relative timing from ship's broadcasts. Absolute timing from VNG. Clock timing from clockwork timer.	1 Willmore Mk2 seismometer, nominal period 1 second.	Willmore recorder. ¼-sec galvo. Recording speed 240 mm/min.
University of Melbourne (C. Kerr-Grant)	Labtroix receiver	Relative timing from ship's broadcasts. Absolute timing from VNG	S.I.E. geophones	S.I.E. P19 recorder. 24 channels.
University of Melbourne (P. Gunn)	Traeger transceiver	Relative timing from ship's broadcasts. Absolute timing from VNG	3 Willmore Mk2 seismometers, nominal period 1 second.	Willmore recorder ¼-sec galvos. Recording speed approx 400 mm/min

Organisation	Radio equipment	Timing	Geophones or Seismometers	Recording
Commonwealth Dept of Works (D. Dyson, J. Devitt)	Traeger transceiver	Relative timing from ship's broadcast. Absolute timing from VNG	Hall-Seers 12-c/s geophones at 55-ft take-outs.	SIE P19 recorder, 12 channels.
University of Queensland (Dr. J.P. Webb)	Eddystone transistorised receivers.	Crystal chronometer coupled to VNG. Relative timing from ship's broadcast. Absolute timing from VNG.	4 Hall-Seers 2-c/s geophones at 1000-ft take-outs. 2 Hall-Seers 1-c/s geophones at 300-ft take-outs	SIE GA-19R amplifiers into a 24-channel recorder.
University of Queensland (Under Dr. J.P. Webb) Two parties	Labtronix receivers	Labtronix crystal chronometer Locked on VNG	2 Hall-Seers 2-c/s geophones.	Carnegie type DTM 2-channel recorders. TR2 transistorised amplifiers. Recording speed 2 mm/s.
University of Sydney (Dr A.A. Day)			Willmore Mk2 seismometer, nominal period 1 second.	Willmore recorder operating off a.c. mains supply
BMR Port Moresby	For equipment see Ripper, 1966.			

Organisation	Radio equipment	Timing	Geophones or Seismometers	Recording
BMR Daru Tapini Kerema	Labtronix fixed frequency receivers locked on VNG	Absolute timing from VNG through BMR NCD2 timing units.	1 Willmore Mk1 seismometers, nominal period 1 second.	U.E.G. ER 230 pen recorders. Paper speed 180 mm/min.
BMR Sogeri	Labtronix receiver	Absolute timing from VNG	1 Willmore Mk 2 seismometer, nominal period 1 second.	Strip chart recorder. Recording speed 21 min/s.

The seismic observatory at Charters Towers operated by University of Queensland was asked to record Group A shots (see Plate 3).

The Australian National University deployed three mobile recording crews in the Northern Territory to record Group D shots (Plate 6). The ANU array at Warramunga was prepared to record Group D shots.

BMR Observatory staff at Port Moresby had limited success in operating a set of exploration refraction equipment at Daru (Denham, 1968).

The Queensland Geological Survey provided two geologists to work in conjunction with the University of Queensland parties. The University College of Townsville provided a meeting place for particpants before field operations began.

3. SHOT POINTS

Positions

The responsibility for positioning the ship was left to the R.A.N. (see Appendix 1). No land-based range-finding equipment was available so that the only methods used for positioning the ship were by taking fixes on landmarks, ship's radar, and by celestial navigation. For all but the last two shots it was possible to obtain fixes and the positions were derived from Admirality charts on board the ship. For

the last two shots (15 and 16) the only method of determining position was by sun shots using a sextant, and the resulting accuracy in these shots is not very good (approx. ± 0.7 km).

For the majority of shot locations, fixes were made on landmarks and this should enable a position to be quoted to 0.1 of a minute of arc provided the landmarks can be identified on air photographs, which cover most of Queensland. On board the ship the positions were plotted on Admiralty charts, which are probably not as accurate as the land surveys. It seems to be the practice on board the ship to quote positions to the nearest minute of arc on some occassions and these are the figures which were available immediately after the project. The eventual positions of the shots are given in Appendix 2.

As transpired on this project, no permanent record of the ship's sitings was kept by the R.A.N. and the ship's charts were cleaned of pencil lines shortly after the first estimates of the positions were noted. The net result is that the positions of many shots are only known to ± 0.5 minutes of arc despite the fact that fixes and radar sitings were capable of fixing to far higher accuracy. For this reason, in future, a geophysicist on board the ship should keep a check on all navigational notes, charts, etc, and make sure there is a permanent record of sitings. The R.A.N. will not allow their own charts to be taken from the ship so that they should be provided with a second set of charts which will be handed over to the person collecting results after the project is finished.

Shipborne recording and timing

Records of the shot instant were made on a Kelvin Hughes 4-channel pen recorder running with a paper speed of 8 cm/s. The four channels were used as follows:

(1) Mercer chronometer pulses ($\frac{1}{2}$ sec on, $\frac{1}{2}$sec off).

(2) Time break from shot box.

(3) Output from tone-generator.

(4) Ship's receiver used for VNG time signals and monitoring the ship's firing sequence broadcasts (see Appendix 1).

The Mercer chronometer was rated with the VNG signal before and after the shot. Unfortunately the chronometer was found to have a very large rate, of the order of -0.1 s/min and this fault could not be rectified on board the ship. This large rate caused the error in the timing of Group A and B shots to be quite large (± 0.020 second). For shots 4 and 5 the accuracy of timing was further reduced because of power failures on board the ship immediately after the shots, making it impossible to obtain a time check. The chronometer was adjusted at the BMR Geophysical Observatory, Port Moresby, and the rate for shots of Group C and D was much improved. The accuracy of timing was correspondingly improved.

The various connections for the chronometer, shot box, and tone generator were incorporated in a BMR Shot Timing Unit (STA 2).

There was a measured delay of 10 ms. between the detonation of the charge and the transmission of the shot instant over the ship's radio.

The accuracy of timing would have been better if VNG had been recorded throughout the time of the shot and not just for a short time about 15 minutes before and 5 minutes after the shot. There was quite a lot of interference from the ship's transmitter during the shot-instant broadcasts but this might have been overcome by using a suitably located receiver and aerial.

A further improvement in accuracy and reliability would be obtained if a crystal clock were available to replace the mechanical chronometer. It is not difficult to obtain a rate of 10 s/day with a crystal clock and this would reduce the dependence on VNG time signals at the shot instant. On board the ship it was found that fairly reliable time signals from VNG could be obtained at night on 12005 and 7515 kc/s but during the day reception was unreliable and it was sometimes difficult to pick up at shot times.

Examination of the shot times in Appendix 2 of this report reveals that the actual shot instant varied from 3.22 seconds to 1 minute 58.609 seconds after the shot time announced on the ship's information broadcasts. This does not matter as long as all the seismic recording stations hear the ship's broadcasts clearly but oral reports from station operators indicate that reception was often very poor. In future experiments of this type, every effort should be made to fire the charge within a second of the advertised minute of the shot. This gives those seismic recording crews with high speed recorders a chance of recording the shot even though they cannot hear the ship's broadcast at the actual shot time.

4. RECORDING SITES

A set of general instructions sent to the seismic crews working in the Cape York Peninsula region is shown in Appendix 3. For a number of reasons some of the recording sites had to be changed and the eventual sites occupied during each group of shots are shown in Plates 3, 4, 5, and 6. In addition to the recording sites in the Cape York Peninsula region, shots 15 and 16 were recorded by the ANU array at Warramunga and at three outstations in a line from Warramunga to shots 15 and 16. ANU used a light aircraft to deploy their seismic crews and this seemed to work quite well for the few days involved in the type of country on the south-western side of the Gulf.

The University of Twonsville Geological Dept kindly let the BMR and other participants in CRUMP use their offices as a meeting place. Most people had to pass through Townsville to get to their recording stations so this provided an opportunity for everyone to meet each other and discuss common problems. Some air photographs were made available to participants, giving them some idea of the country. Appendix 4 was issued to interested parties, giving some

indication of the state of roads in Cape York Peninsula.

The positions of seismic recording stations on land were chosen to tie in with the gravity and land survey traverses carried out by the BMR and the Queensland Lands Dept. Gravity and elevation control stations are indicated by bench-marks on small piers at the side of the road (see Appendix 3). The majority of stations were in areas covered by air photographs and these could be obtained from BMR. Provided the station could be accurately located on the air-photo (sometimes it was difficult because of recent developments in roads, etc.) the position could be related to the reference points on each photo and these were then tied in with the Division of National Mapping grid. This work was done by the BMR Drawing Office staff. The resulting accuracy is probably the same as the overall accuracy of the Lands Department survey (approx. $\pm$ 6 seconds of arc). The recording site positions are therefore justifiably quoted to 0.1 minute of arc.

5. TRANSPORT

It was anticipated that many of the sites for seismic recording stations would be difficult to reach because of the poor roads in many of the districts. A report from the BMR geological party in Cape York Peninsula on the state of the roads high-lighted some of the difficulties in the area (Appendix 4). Four BMR parties were equipped with long-wheel-base Land Rover vans or utilities and the other two were equipped with International 4 x 4 seismic recording vans or utilities. The only serious breakdowns were caused by a broken tail shaft to one of the seismic recording vans (a replacement had to be flown in) and a broken steering rod, which was mended with fence wire.

Most of the University parties and the Commonwealth Works Dept were equipped with Land Rovers of one sort or another. Two-wheel-drive vehicles used included a B.M.C. Mini-Moke and a V.W. Combi van, and they found the roads not quite so easy. The V.W. succeeded in getting past Moreton Telegraph Station in Cape York but was accompanied most of the way by a BMR Land Rover and driver seconded to the University of Melbourne party. This Land Rover broke a back axle at Bamaga near the tip of Cape York but succeeded in getting back to Cairns on front-wheel-drive.

The road maps of the area are by no means up to date and it is advisable to consult with local residents before going off the 'main' roads.

6. COMMUNICATIONS

All BMR parties, the Commonwealth Department of Works, and a number of University parties were equipped with Traeger transceivers (either the TM 2 or TM 3 models). The ship's broadcast frequencies

and schedules are given in Appendix 1. The ship was asked to keep a listening schedule for 10 minutes after each of the information broadcasts at 0600, 1130, and 1700 hr for messages from BMR Party No. 3. Otherwise the only other way of communicating with the ship was through FOCAF, Sydney.

The frequencies used during the various periods of the day were chosen in conjunction with the R.A.N. communications staff to give the best reception over the distances involved.

Generally the ship's transmissions were quite well received during the early morning and during the day but reception deteriorated in the early evening owing to local thunderstorms. Very often the ship's transmissions were not received as well as other small stations in the same frequency band and this suggested that a more powerful ship's transmitter may be desirable. Seismic stations far from the ship reported that useful ship's time signals could only be recorded during the daytime. The time signal tone from the ship was around 1100 c/s and not 900 c/s as stated in the trial instructions, which may have caused trouble with those using narrow band-width filters.

Intercommunication between seismic recording stations was by arrangement with the individual parties either by radio, by telephone, or through the Air Ambulance Service. In addition, all stations could get in touch with BMR Party No. 3 through the Air Ambulance Service and these messages could be passed to the ship.

However, in practice any system of intercommunication which depends on outside agencies like the Air Ambulance Service proves difficult because of the speed at which projects of this type take place. In addition BMR Party No. 3 had a faulty transmitter so that direct communication with the ship never took place. The only communication to the ship was by telephone to FOCAF, Sydney, and this was used quite frequently. However, FOCAF only had one schedule with the ship per day so that developments had to be forseen in advance.

Fortunately BMR Party No. 3 was well equipped with receivers so that most transmissions either between seismic parties or from the ship were received and any action involving the ship taken by communicating through FOCAF.

Comments

The loose system of intercommunication used on CRUMP works all right provided there are no changes in the ship's programme, but this is something that rarely happens and therefore some better system should be employed in the future. The use of outside agencies such as the Air Ambulance Service, FOCAF, and the P.M.G. introduces unnecessary complications. In future projects of this kind it should be written in to the R.A.N. trial instructions that there will be two-way communications between the ship and the shore parties. The shore parties as well as having small transceivers must be equipped with one powerful transceiver which will act as communications centre; a geophysical field party leader, with authority to make alterations to the project, should be in charge

of this centre. In addition a geophysicist must be on board the ship to advise the captain on all aspects of the project. This is in addition to any BMR electronics staff which may be on board purely for the purpose of shot firing and recording. The geophysicist on board the ship must be allowed to use the ship's transceiver to communicate with shore parties.

VNG reception

On shore VNG reception was found to be adequate for time checks on most occasions. For putting a time signal on record at the time of the shot, reception was probably as good as could be expected (approx. 75% successful recordings). Unfortunately, an experimental VNG timing signal was in operation during October. The length of the seconds pips was changed in a four-minute cycle and during the shorter pulse sequences it was sometimes difficult to tune into the broadcast through noise.

7. DISCUSSION

Most of the recording crews for CRUMP had taken part in similar projects before so that generally speaking they were able to anticipate difficulties. The crews were, however, very much at the mercy of the R.A.N. who were detonating the charges. The main difficulty was in trying to keep up with changes in the ship's firing programme using limited communications. The ship failed to hear any radio transmissions from field party no. 3 and eventually only limited communication was kept through FOCAF in Sydney. In future projects it would help greatly if a local communications centre could be maintained. The poor communications also hindered the captain of the ship when he needed technical advice on the design of the experiment in the various contingencies which arose. This problem could also perhaps be eliminated by having a geophysicist on board the ship who would assist with shot timing and positioning.

8. REFERENCES

DENHAM, D. 1968 Carpentaria Region Upper Mantle Project 1966, Results from recordings made in Papua. Bur.Min.Resour.Aust.Rec. 1968/15

RIPPER, I.D. 1966 Seismograph calibrations, Port Moresby Geophysical Observatory, TPNG 1958-1962. Bur.Min.Resour.Aust.Rec. 1966/185

APPENDIX 1

TRIAL INSTRUCTION 2/66 FOR THE CARPENTARIA REGION UPPER MANTLE PROJECT

These instructions were issued for the conduct of seismic exploration in the Cape York, Torres Strait, and Gulf of Carpentaria region between 17th September and 11th October 1966 by the Director of Weapons and Electrical Engineering, Navy Office, Canberra, A.C.T. on 5th August 1966.

Distribution of instructions	Copies
Flag Officer Commanding, H.M. Australian Fleet.	2
Flag Officer-in-Charge, East Australia Area.	3
Director of Weapons and Electrical Engineering, Navy Office.	2
The General Manager, H.M. Australian Naval Dockyard, Garden Island.	1
The Hydrographer, R.A.N.	1
The Captain of the Port, Sydney.	1
The Captain, H.M.A.S. KIMBLA.	3
The Director of Scinetific Services, Navy Office,	1
The Director, Bureau of Mineral Resources, Geology and Geophysics, Canberra.	30
Mr. R. Underwood, Australian National University, P.O. Box 4, Canberra.	1
Mr. C. Kerr-Grant, Department of Geology and Mineralogy, University of Melbourne.	1
Professor S.W. Carey, University of Tasmania.	1
Professor J.J. Frankel, Department of Applied Geology, University of NSW	1
Professor C.E. Marshall, Department of Geology and Geophysics, University of Sydney.	1
Professor J.C. Jaeger, Department of Geophysics, Australian National University, Canberra.	1
Professor J.H. Carver, Physics Department, University of Adelaide, SA.	1
Mr. A.K. Denmead, Department of Mines, Queensland.	1
Dr. P.J. Stephenson, University College, Townsville.	1
Observer-in-Charge, Geophysical Observatory, Port Moresby.	1
Observer-in-Charge, Mundaring Geophysical Observatory, WA.	1
Senior Geologist, Darwin.	1
Professor R.T. Prider, University of West Australia, Nedlands.	1
The Secretary, Division of Fisheries, Department of Primary Industries, Canberra.	1
Naval Officer-in-Charge, Queensland, Brisbane.	1
Deputy Naval Officer-in-Charge (New Guinea), Port Moresby.	1

GENERAL

Between 17th September and 11th October 1966 the Royal Australian Navy will be assisting the Bureau of Mineral Resources in conducting extensive off-shore seismic experiments. The project has been given the nickname "CRUMP ONE".

H.M.A.S. KIMBLA will embark 12 tons of depth charges before departure from Sydney. These charges will be assembled into ½-ton and 1-ton shots and detonated in positions fixed as accurately as navigational aids in the area will allow.

The aim of the experiment

"CRUMP ONE" is a Bureau of Mineral Resources programme with the following aims:

1. to investigate the geological structural relationship of the Australian mainland to New Guinea;

2. to determine the thickness of the Earth's crust in the Cape York, Torres Strait, and Gulf of Carpentaria area:

3. to investigate the nature of the upper part of the Earth's mantle in this region; and

4. to determine the geological formations in the area which have a bearing on its oil potentialities and mineral prospects.

The results will be a step in the exploration of the continental margins around Australia. The exploration of these margins around other countries is now being extensively undertaken. The crust comprises the upper layers of the Earth, down to a depth of 30 or 40 miles and has a varied composition containing many types of rocks. Below this, is the mantle, which is thought to be of almost uniform composition through most of the solid earth.

Over the land, geologists and geophysicists explore to find minerals, oil, etc. and to understand the geographical features of the Earth.

Under the sea this exploration is much more difficult and until recently, was almost impossible. Drilling at sea is a very slow and expensive process and is usually undertaken only when there is a chance of finding oil. This project is an attempt to go deeper, to determine the depth of the Earth's crust, the thickness of its deeper layers and the composition of the upper part of the Earth's mantle in this region, using the seismic method of exploration: this is by detonating explosive charges and measuring the time of travel of the wind and shock waves to sensitive recorders at known positions.

Shot positions

Area	Reference point	Latitude	Longitude	Size of Explosion (tons)	Approx. depth (Km)
Group A					
Magnetic Passage	Myrmidon Reef	18°16'S	147°18'E	1	40
Steamer Channel	N. Barnard Is.	17°42'S	146°12'E	½	12
Steamer Channel	Russel Is.	17°15'S	146°03'E	½	10
Flora Pass	(N.W. Reef				
	(Channel Reef	16°55'S	146°25'E	1	33
Trinity Opening	Norman Reef	16°24'S	146°00'E	1	30
Steamer Channel	Green Is.	16°45'S	145°55'E	½	20
Group B					
Princess Charlotte Bay	Pipon Is.	14°05'	143°50'	½	17
Princess Charlotte Bay	Tahey Reef	14°00'	144°35'	1	10
Second 3-Mile opening	(Ham. Reef-Franklin Reef)	13°04'	143°52'	1	20
Group C					
Torres Strait	Cape York	10°35'	142°30'	½	10
Torres Strait	Dove Is.	10°00'	143°04'	½	12
Torres Strait	Stephens Islet	9°30'	143°30'	1	25
Torres Strait	Bramble Cay	9°10'	143°54'	1	24
Group D					
Gulf of Carpentaria	Mitchell River	15°40'	141°10'	½	15
		16°10'	140°30'	½	12
	Bountiful Is.	16°43'	139°57'	1	15

Location and number of receiving stations

The location and number of receiving stations are shown on "CRUMP" Chart No. 1 and on air photographs covering each station area. The geophysicist in charge of each station is to record as accurately as possible each geophone position.

Programme

Event or Shot No.	Date/time (Zone - 10)	Shot position Lat. (S)	Shot position Long. (E)	Shot size (tons)
Sail Brisbane	170830 Sept.			
Shot 1	210350	18°16'	147°18'	1
Shot 2	210650	17°42'	146°12'	½
Shot 3	211250	17°15'	146°03'	½
Shot 4	211750	16°55'	146°25'	1
Shot 5	220750	16°40'	146°14'	1
Shot 6	221150	16°53'	146°02'	½
Arrive Cairns	221530 Fuel			
Sail Cairns	231330			
Shot 7	241750	14°00'	144°35'	1
Shot 8	250350	14°05'	143°50'	½
Shot 9	251250	13°04'	143°52'	1
Sail Second Three Mile Opening	251430			
Arrive Pt. Moresby	270900 Fuel			
Sail Pt. Moresby	300830			
Shot 10	011050 Oct.	9°10'	143°54'	1
Shot 11	011550	9°30'	143°30'	1
Shot 12	012250	10°00'	143°04'	½
Shot 13	020750	10°35'	142°30'	½
Shot 14	040850	15°40'	141°10'	½
Shot 15	041650	16°10'	140°30'	½
Shot 16	050850	16°43'	139°57'	1

NOTE. This programme allows for one day contingency for "CRUMP ONE" and for bottom sampling in the Gulf of Carpentaria for the BMR.

Responsibility

Project "CRUMP ONE" is a complex experiment involving both the R.A.N., Bureau of Mineral Resources, and other bodies. The cost of each shot is very high and it is imperative that every effort be made by participating units to record all possible trials information. The Captain and project team on board KIMBLA have had considerable experience in the conduct of scientific trials at sea and unless delayed by adverse weather, equipment failure, or a request made by the liaison officer, the trial will proceed as planned. The various authorities responsible for the trial are as follows:

(a) The Captain, H.M.A.S. KIMBLA, Lt. Cdr. P.M. Cumming, R.A.N. Responsible for all aspects of the trial relating to KIMBLA, in particular handling and siting the charges and safety aspects of the trial.

(b) Officer in Scientific Control (OISC) Mr. J. Dooley BMR. Mainly responsible for all scientific aspects of the trial. He will be stationed at Canberra. Telephone 499272. His Deputy, to be arranged, will be stationed in the Townsville area.

(c) R.A.N. Liaison will be FOCAF STAFF at Fleet Headquarters Garden Island. Telephone Sydney 350444 Extension 850.

Procedure to be adopted in case of breakdown of a recording station

Every effort must be made to meet the trials programme set out above. If this cannot be achieved, however, the geophysicist in charge of the station involved is to notify the Deputy OISC in the Townsville area or the OISC.

A delay in the programme for this cause will only be approved by the OISC in exceptional circumstances and H.M.A.S. KIMBLA will be notified by a signal from Liaison Officer. Should a variation of the programme be approved, H.M.A.S. KIMBLA will notify all receiving stations at the next communication schedule (see below).

Procedure to be adopted in case of failure of a charge to fire

If a charge fails to fire, H.M.A.S. KIMBLA will notify all receiving stations and proceed to recover the charge. The charge will be replaced and figuring firing will take place one hour or two hours after the scheduled time. If the delay is going to be longer than two hours, decision will be made by the OISC and Captain, H.M.A.S. KIMBLA, on whether the shot is to be abandoned.

Adverse weather could require a charge to be fired as soon as it is deployed; receiving stations should be prepared for this possibility.

Communication schedule

The call sign for H.M.A.S. KIMBLA is NK (November Kilo). H.M.A.S. KIMBLA will notify all recording stations of the firing programme each day shots are to be fired on the frequency or for the hour at 0600, 1130, and 1700. Frequencies to be used are as follows:

All times local 0001 to 0800 hrs on 2140 kc/s
0800 to 2000 hrs on 6815 kc/s
2000 to 2359 hrs on 4630 kc/s

A warning will be broadcast by H.M.A.S. KIMBLA commencing 10 minutes to the hour two hours before the shot is to take. This warning will be broadcast for 5 minutes duration every half hour at 10 minutes to the hour, and 20 minutes past the hour on the frequency for that time. Shots are to be fired at 10 minutes to the hour.

Warning and firing sequence

- 2 hours	5-minute warning broadcast	(10 min to the hour)
-1½ hours	" " " "	(20 min to past the hour)
- 1 hour	" " " "	(10 min to the hour)
- ½ hour	" " " "	(20 min past the hour)
-10 minutes	2 " " "	
- 2 minutes	a warning broadcast	
- 1 minute	KIMBLA announce "November Kilo, CRUMP shot No.... follows in 1 minute."	

Immediately following this, a keyed tone modulated carrier with a 5-1 mark to space ratio will follow until approximately 10 seconds before the shot. At -10 seconds a continuous steady tone of 900 c/s will follow. The termination of this tone will indicate the instant of fire. At + 10 seconds a 900-c/s pip will follow and each successive 10 seconds following this for two minutes. On completion, H.M.A.S. KIMBLA will announce "November Kilo, that was shot No..... Shot No..... will follow at.....

Dummy firing sequence

A dummy firing sequence will be carried out five hours before the first shot. This is necessary because of the distances involved, and H.M.A.S. KIMBLA will be as close as possible. This is to check the radio receiving equipment at all receiving stations. The transmission will be on the frequency for the hour and will be relayed by local radio stations if this can be arranged. The message will be as follows:

> "November Kilo, CRUMP dummy firing sequence follows in one minute. Immediately following this a keyed tone modulated carrier with a 5-1 mark to space ratio will follow for about 20 seconds. This will be followed by a 10-second continuous note of 900 c/s. Finally a succession of 900-c/s pips for two minutes."

Safety

The TAS or CD officer embarked will be responsible to the Captain, H.M.A.S. KIMBLA, for the safety of fitting, priming, and firing the charges. He will be personnally responsible for the safety of the firing circuits and connect them to the blaster after the 2-minute warning has been broadcast. Firing will be initiated only on the authority of the Captain.

Warning to submarines and notice to mariners

H.M.A.S. KIMBLA will raise all requisite warnings and notices to mariners. In accordance with CANO 58/65 international G.F.D. is to be transmitted continuously from five minutes before firing each shot using CW.

Trial records

All records of the trial taken in H.M.A.S. KIMBLA are to be handed to Mr. D.M. Morton before he disembarks. All records taken at individual receiving stations are to be forwarded to Mr. J.C. Dooley in accordance with separate instructions to be issued.

Personnel

The following personnel to joing H.M.A.S. KIMBLA in Brisbane by 16 September 1966.

One TAS or CD Officer	Navy
Mr. D.M. Morton	BMR

One Survey Recorder (not yet confirmed)

Installation of equipment in H.M.A.S. KIMBLA

Scientific equipment for the trial will be embarked in H.M.A.S. KIMBLA at Brisbane and will be installed and checked on passage to the first shot position.

Tape Recording

If the six-channel tape recorder is used, Track Identity will be as follows:

1. Sequence timer output direct
2. Chronometer direct
3. Fire pulse
4. Output ship's transmitter
5. Hydrophone output
6. Announcements

APPENDIX 2

SUMMARY OF SHIPBORNE OPERATIONS

17/9/66 H.M.A.S. Kimbla sails from Brisbane after picking up BMR officer with shot firing and recording equipment.

20/9/66 Ship's broadcasts at 11.30 and 1700 indicate delay in firing Shot 1 and a change in the position of shot 1. The shot was delayed by the late arrival of the ship and the position of the shot was changed because to steam out to the original position would have meant a further delay. The late arrival also meant that Shots 2, 3, and 4 were delayed.

21/9/66 SHOT 1 fired at 06.50 33.16 secs in position 18°00.0'S 146°25.0'E in 14 fathoms of water. Size of charge, 1 ton. The position was some distance from the originally intended and this is to be regretted because the original position was chosen to give a better pattern of phases and velocities than many of the other shots.

SHOT 2 fired at 11.50 32.50 sec in position 17°42.0'S 146°12.0'E in 11 fathoms of water. Size of charge, ½ ton.

SHOT 3. The firing cable broke causing a further delay of 1 hour. On the first attempt the charge failed to fire and it was recovered and the firing cable repaired again. This caused a delay of a further 2 hours. Eventual firing time was 19.50 45.74 secs at position 17°15.0'S 146°03.0'E in 10 fathoms of water. Size of charge, ½ ton.

After Shot 3 the ship broadcast its intention of firing Shot 4 at 23.50.

SHOT 4 fired at 23.51 58.60 sec in position 17°02.0'S 146° 18.0'E in 26.5 fathoms of water. Size of charge, 1 ton. Shortly after the shot there was a power failure on board the ship which caused a large timing error (± 0.2 sec).

22/9/66 SHOT 5 fired at 07.50 09.17 sec at position 16°40.0'S 146° 14.0'E in 32 fathoms of water. Size of charge, 1 ton. Again a power failure just after the shot time caused a large timing error (± 0.2 sec).

SHOT 6 fired at 11.50 11.29 sec at position 16°53.0'S 146° 0.2.0' in 20 fathoms of water. Size of charge, 1½ ton. End of GROUP A shots. Ship proceeded to Cairns.

23/9/66 Ship proceeded north to site of GROUP B shots while seismic recording parties changed sites on land.

24/9/66 SHOT 7 fired at 17.50 03.22 sec at position 13°59.8'S 144° 35.0'E in 15.5 fathoms of water. Size of charge, 1 ton.

25/9/66 SHOT 8 misfired on the first attempt at 03.50 and the charge was recovered and reset. This caused a 3-hour delay in firing. Shot eventually fired at 06.50 22.57 sec at position 14°05.0'S 143°50.0'E in 8 fathoms of water. Size of charge, ½ ton.

SHOT 9 fired at 16.50 08.85 sec at position 13°04.4'S 143° 51.0'E in 12 fathoms of water. Size of charge, 1 ton.

After Shot 9 the ship proceeded to Port Moresby to refuel. A chronometer which was causing difficulty in timing the shots was adjusted and considerably improved. In response to a telegram from D. Finlayson and a further request by J.C. Dooley, the ships radio transmitter was checked and reported to be transmitting at full power by the radio operator.

1/10/66 The firing of Shot 10 was delayed 7 hours by the late arrival of the ship.

SHOT 10 fired at 17.50 19.05 sec at position 09°10.0'S 143° 54.0'E in 22.5 fathoms of water. Size of charge, 1 ton.

At this stage some recording sites were having difficulty in receiving the ship's broadcasts so that a telegram was sent to the ship via FOCAF from D. Finlayson asking if it was possible to increase the power of the transmitter. The ship thereupon broadcast two dummy firing runs, one at 22.50 on 1/10/66 on frequency 4630 kc/s and the other at 08.50 on 2/10/66 on frequency 6815 kc/s and requested all seismic stations to report to O.I.S.C., which in the majority of cases was impossible at short notice.

2/10/66 A telephone call to FOCAF by D. Finlayson revealed that the ship had proposed to fire Shots 11, 12, and 13 at 22.50 on three successive days thereby ruling out any possibility of shots being fired in the Gulf of Carpentaria because of the ship's intended time of arrival in Darwin. This proposal was very strongly opposed by J.C. Dooley and D. Finlayson and FOCAF were asked to tell H.M.A.S. KIMBLA to proceed with firing at the soonest possible opportunity and to stick as closely as possible to the published programme. In particular it was stressed that shots in the Gulf of Carpentaria were most important.

SHOT 11 fired at 22.50 17.88 sec at position 09° 30.6'S 143° 28.3'E in 25.5 fathoms of water. Size of charge, 1 ton.

3/10/66 SHOT 12 misfired at 07.50 but was recovered and fired successfully at 09.50 05.59 sec at position 10°00.0'S 143°04.0'E in 9.5 fathoms of water. Size of charge, ½ ton.

The delay in Shot 12 further jeopardised the shots in the Gulf of Carpentaria and therefore with the agreement of J.C. Dooley, D. Finlayson requested FOCAF to ask the ship to cancel Shot 13 and proceed with the firing of Shots 14, 15, and 16 in the Gulf. These were deemed to be far more important than shots in the Torres Strait at this stage.

SHOT 13 was cancelled at 1700 broadcast and ship proceeded into Gulf of Carpentaria. While steaming in the Gulf the ship encountered strong headwinds which reduced its net cruising speed from 8 to 5 knots.

5/10/66 At 06.00 the ship broadcast its intentions of having a dummy firing run at 15.50 and firing Shot 14 at 21.50 Shot 15 at 07.50 on 6/10/66, and Shot 16 at 19.50 on 6/10/66.

At 1550 the ship amended its timetable and announced its intention of firing Shot 14 at 07.50 on 6/10/66, Shot 15 at 13.50 on 6/10/66, and Shot 16 at 10.50 on 6/10/66.

6/10/66 SHOT 14 misfired at 07.50.

SHOT 14 delayed at 09.50.

SHOT 14 delayed at 10.50.

SHOT 14 misfired at 11.50 and when the charge was recovered it was found to be damaged and was therefore abandoned.

At 12.20 the ship announced its intention of firing a Shot 15 at 13.20.

SHOT 15 fired at 13.20 58.46 sec in position 15° 33.6'S 141° 00.5'E in 12 fathoms of water. Size of charge, 1 ton.

The ship announced that Shot 16 would be fired at 17.50.

SHOT 16 fired at 17.20 34.32 sec at position 15° 33.8'S 141° 00.5'E in 12 fathoms of water. Size of charge, 1 ton.

APPENDIX 3

INSTRUCTIONS ISSUED BY BMR TO RECORDING CREWS

Meeting of field parties for final briefing

Townsville University College have made available a room in their Geology Dept for the use of the participants in CRUMP. It is therefore proposed that field parties should meet Mr J.C. Dooley or his representative in Townsville on their way north so that they may have an opportunity to obtain the latest information on the project. Someone will be in the University College Geology dept to answer any questions at the following times:

Friday 16/9/66	afternoon
Saturday 17/9/66	forenoon
Monday 19/9/66	forenoon

Dr P.J. Stephenson of the Geology Dept has also arranged for the use of a photographic dark room and minor workshop facilities in the college.

Supply of maps

The 1:250,000 series of maps has been used in drawing up plans of the project and it is suggested that field parties should obtain copies of these maps for use in the field. After the project is finished, participants will be asked to send a 1:250,000 copy map to Mr J.C. Dooley with their positions marked on it as accurately as possible. The participants may then be asked to pick out their positions more accurately on 1-inch maps or air photographs supplied by the BMR. Some air photographs may be available to field parties in Townsville before they leave for their recording sites.

CRUMP survey seismic recording sites

The table below shows a recommended distribution of recording stations for the various groups of shots. The numbers correspond to the numbers on the sites shown in Plate 1. The names for the various sites are given below.

	shot group				
	A	B	C	D	Recorders
BMR No. 1	10	23	23	23	24-channel spread
BMR No. 2	5	16	19	19	24-channel spread
BMR No. 3	1	30	30	11	Willmore
BMR No. 4	2	20	20	18	Willmore

	shot group				
	A	B	C	D	Recorders
BMR No. 5	3	15	17	17	Willmore
BMR No. 6	11	21	21	21	Willmore
Sydney Uni.	13	13	13	13	Willmore
Qld. Uni.	4	24	28	24	2-channel
Qld. Uni.	9	25	27	25	2-channel
Qld. Uni.	6	29	29	26	6-channel
Mbne. Uni.	7	32	32	-	24-channel spread
Mbne. Uni.	12	31	31	22	Willmore
Dept. of Works	8	14	14	14	Spread

Most of the recording sites are situated near homesteads or other features which will be recognisable on air photographs. A lot of the sites are also near the elvation control traverses marked on the map and it is requested that where the sites are some distance from these traverses, some effort be made to estimate the height differences and distances from a bench-mark. These are supposed to be spaced along the elevation traverses at about 5-mile intervals and a sketch of what they look like is shown in Plate 7.

BMR officers who have been up in the area seem to think that it is quite possible to cover 200 miles in a day without trying too hard, even on the worst roads but they do advise that parties travel in convoy wherever possible.

Names of recording sites

1. Millaa Millaa - Innisfail Road
2. Voalbrook H.S.
3. Oak Park H.S.
4. Conjuboy H.S.
5. Wyoming H.S. Turnoff
6. Ravenshoe
7. Little Mulgrave
8. Silkwood
9. Garrumba
10. Almaden
11. Rookwood H.S.
12. Blackdown H.S.
13. Balimba H.S.
14. Highbury H.S.

15. Strathlevenn H.S.
16. Abingdon H.S.
17. Highbury - Vanrook Road
18. Dorunda H.S.
19. Inkerman H.S.
20. Rutland Plains H.S.
21. Edward River Mission
22. Edward River - Strathmay Road
23. Strathmay H.S.
24. Strathburn H.S.
25. Bamboo
26. Stewart River
27. Archer River
28. Weipa Road Turn-off
29. Batavia Downs H.S.
30. Bramwell H.S Turn-off
31. Cockatoo Creek
32. Bamaga

Alterations in shot-point positions

Because of danger to the Cairns - Madang submarine cable, the positions of Shots 5 and 6 in Group A have been changed to the following:

Shot 5

Grafton Passage Lat. 16 40'00"S Long. 146 14'20" E

Shot 6

Steamer Channel Lat. 16 53'00"S Long. 146 02'20"E

Alterations to recording site positions

Because of the change in shot positions in Group A, the sites for three recorders have been altered slightly. The new sites are as follows:

Recording site no. 2	Coalbrook H.S.
Recording site no. 3	Oak Park H.S.
Recording site no. 5	Wyoming H.S.Turn-off

Communications for CRUMP

H.M.A.S. KIMBLA's communications frequencies are given in the Trial Instructions 2/66 from which the following abstract is taken:-

> The call sign for KIMBLA is NK (November Kilo) KIMBLA will notify all recording stations of the firing programme each day shots are to be fired on the frequency for the hour at 0600, 1130, and 1700. Frequencies to be used are as follows:
>
> All times local 0001 to 0800 hrs on 2140 kc/s
> 0800 to 2000 hrs on 6815 "
> 2000 to 2359 hrs on 4630 "

It has been arranged that after each of information braodcasts from H.M.A.S. KIMBLA, there will be a listening schedule for 10 minutes during which H.M.A.S. KIMBLA will listen for BMR Party No. 3 (D. Finlayson, Call Sign 8RA) who will send to the ship any information from the field parties. This will be the only means of communicating with H.M.A.S. KIMBLA directly. 8RA will be transmitting on the frequencies for the hour.

Communications between field parties. BMR parties will be able to intercommunicate on the BMR frequencies 2140, 6815, 4630 kc/s according to the time of day.

BMR call signs:

BMR party No. 1	8RC
BMR party No. 4	8RC
BMR party No. 2	8RQ
BMR party No. 3	8RA
BMR party No. 5	8RR
BMR party No. 6	8RY

In addition 8RA will be able to communicate with the RFDS radio system on 5145 and 7465 kc/s and messages may be sent to 8RA through the RFDS network at homesteads etc.

APPENDIX 4

ROADS IN THE CAPE YORK PENINSULA

This is a report made by the Cape York geological party of the Bureau of Mineral Resources and the Geological Survey of Queensland on 21 August 1966.

Road from Laura to Coen

This road has recently been improved by grading creek crossings and by levelling some dust and sand patches. It has been traversed with some difficulty by a few light two-wheel-drive vehicles (e.g. Volkswagen 1200 saloons), which may have been assisted by four-wheel drive vehicles in sandy or dusty patches.

Road from Coen to Moreton Telegraph Station

This is of formed gravel from Coen to Coen Airfield, 15 miles to the north, and beyond that is an unformed gravel and dirt road. Stretches of the road are sandy or potholed and furrowed. Some creek crossings have been graded recently; others have not and are rough. A few light two-wheel drive vehicles have recently travelled this road, but only with difficulty and with the risk of long delays if they become stuck in sand. The road is easily traversed with a four-wheel-drive vehicle.

Road from Moreton T.S. to Cape York

This is an unformed gravel and dirt track along the telegraph line; its surface is very rough with sandy and rocky patches common. Creek crossings are difficult; some are steep and rocky. To the north, crossings of flowing creeks are steep and muddy. The road is passable only by four-wheel-drive vehicles and an average speed of 10 miles per hour is normal. The Jardine River, 30 miles south of the end of the road at Cape York, is impassable to all vehicles except four-wheel-drive trucks with considerable clearance, as the river is 3 feet 6 inches deep over the crossing and the bottom is muddy.

Road from Coen to Iron Range and Portland Roads

This is an unformed gravel and dirt track with a reasonably good surface as far as Tozers Gap, though it has some sandy and furrowed rocky patches. Through the rain forest north-east of Tozers Gap, creek crossings are steep, muddy, and slippery; bridges over some creeks are old and week. An excellent road connects Iron Range with Portland Roads. Four-wheel-drive is required even between Coen and Tozers Gap, and a winch is essential between Tozers Gap and Iron Range.

Road from Coen to Weipa

Between the Telegraph Line and Merluna, this is a gravel and dirt road with an excellent surface, passable to two-wheel-drive vehicles. From the Merluna turn-off to Weipa the road has rocks or sandy patches and is passable to two-wheel-drive vehicles only with difficulty.

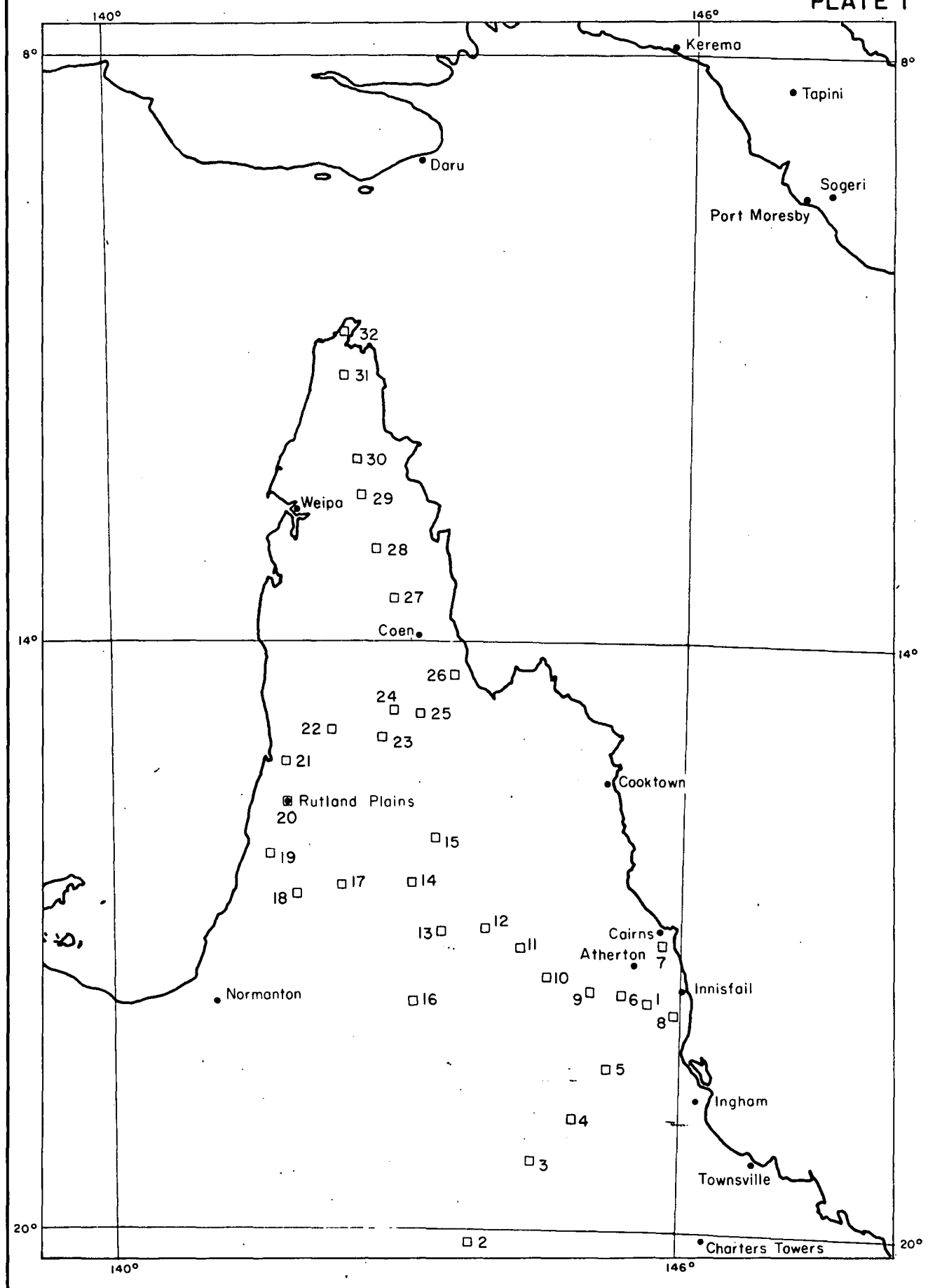
Road from Moreton Telegraph Station to Merluna and Weipa

This is an unformed dirt and gravel road with steep sandy creek crossings. It is only passable to four-wheel drive vehicles.

General warning

All vehicles using these roads are recommended to carry spare axles as axle failure is common in the steep creek crossings.

PLATE 1



PROPOSED RECORDING SITES FOR CRUMP

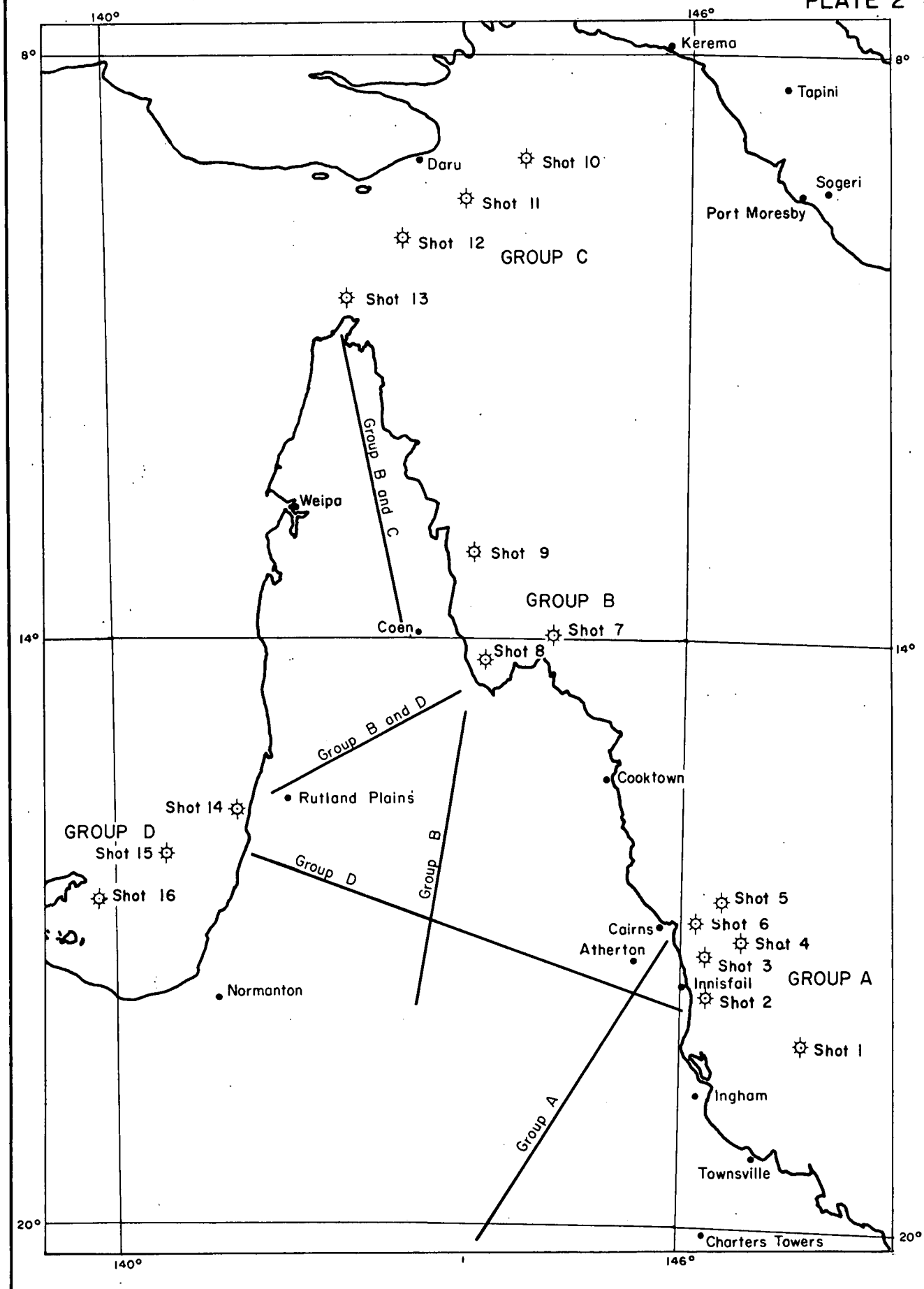
Miles 100 0 100 200 300 Miles

TO ACCOMPANY RECORD N°1968/14

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G 443 – 2

PLATE 2



PROPOSED SHOT LOCATIONS AND RECORDING LINES

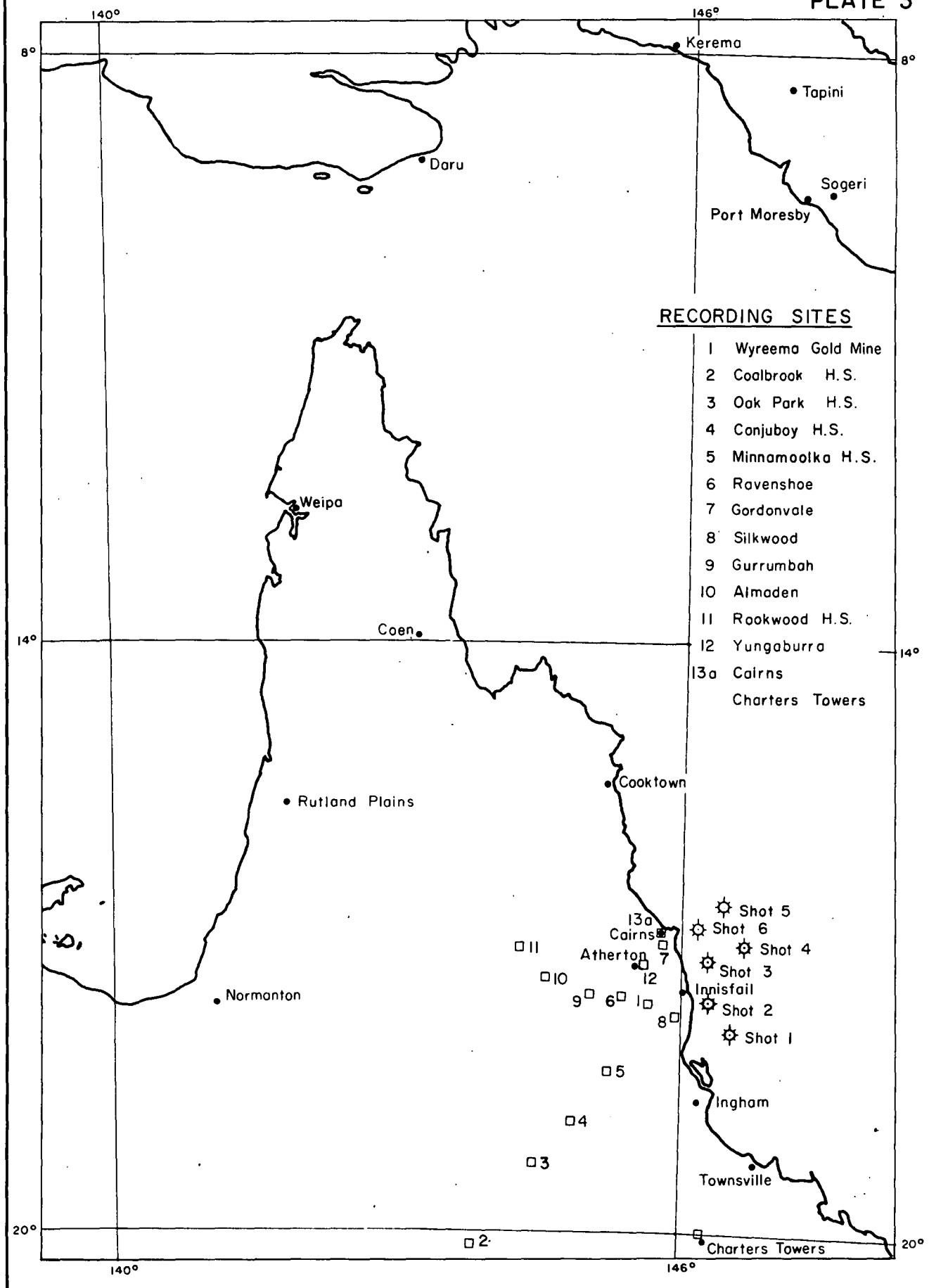
Miles 100 0 100 200 300 Miles

TO ACCOMPANY RECORD N°1968/14

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G 443–7

PLATE 3



RECORDING SITES

1 Wyreema Gold Mine
2 Coalbrook H.S.
3 Oak Park H.S.
4 Conjuboy H.S.
5 Minnamoolka H.S.
6 Ravenshoe
7 Gordonvale
8 Silkwood
9 Gurrumbah
10 Almaden
11 Rookwood H.S.
12 Yungaburra
13a Cairns
Charters Towers

GROUP A SHOTS AND RECORDING SITES

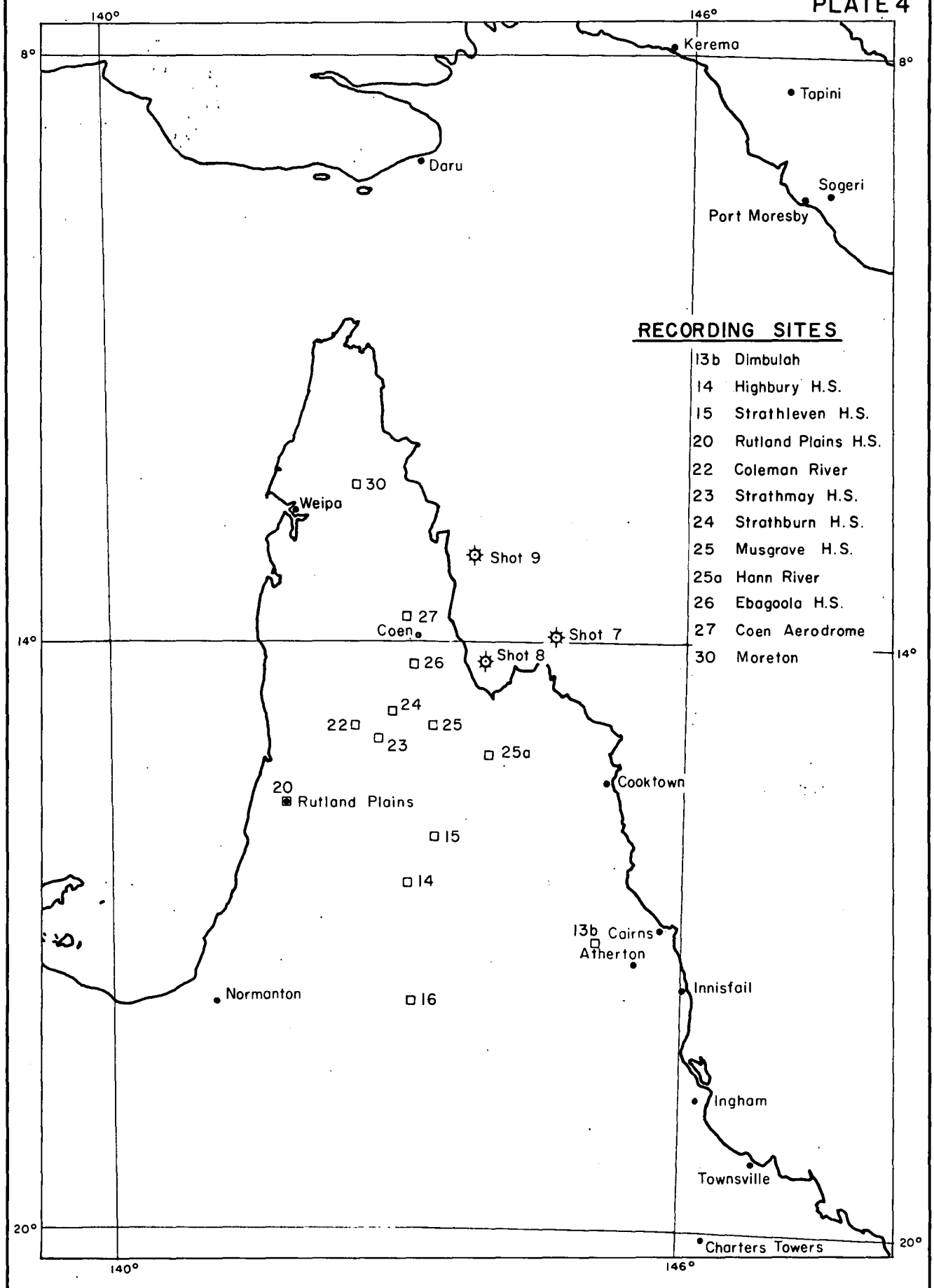
Miles 100 0 100 200 300 Miles

TO ACCOMPANY RECORD N°1968/14

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G 443–6

PLATE 4



RECORDING SITES

13b	Dimbulah
14	Highbury H.S.
15	Strathleven H.S.
20	Rutland Plains H.S.
22	Coleman River
23	Strathmay H.S.
24	Strathburn H.S.
25	Musgrave H.S.
25a	Hann River
26	Ebagoola H.S.
27	Coen Aerodrome
30	Moreton

GROUP B SHOTS AND RECORDING SITES

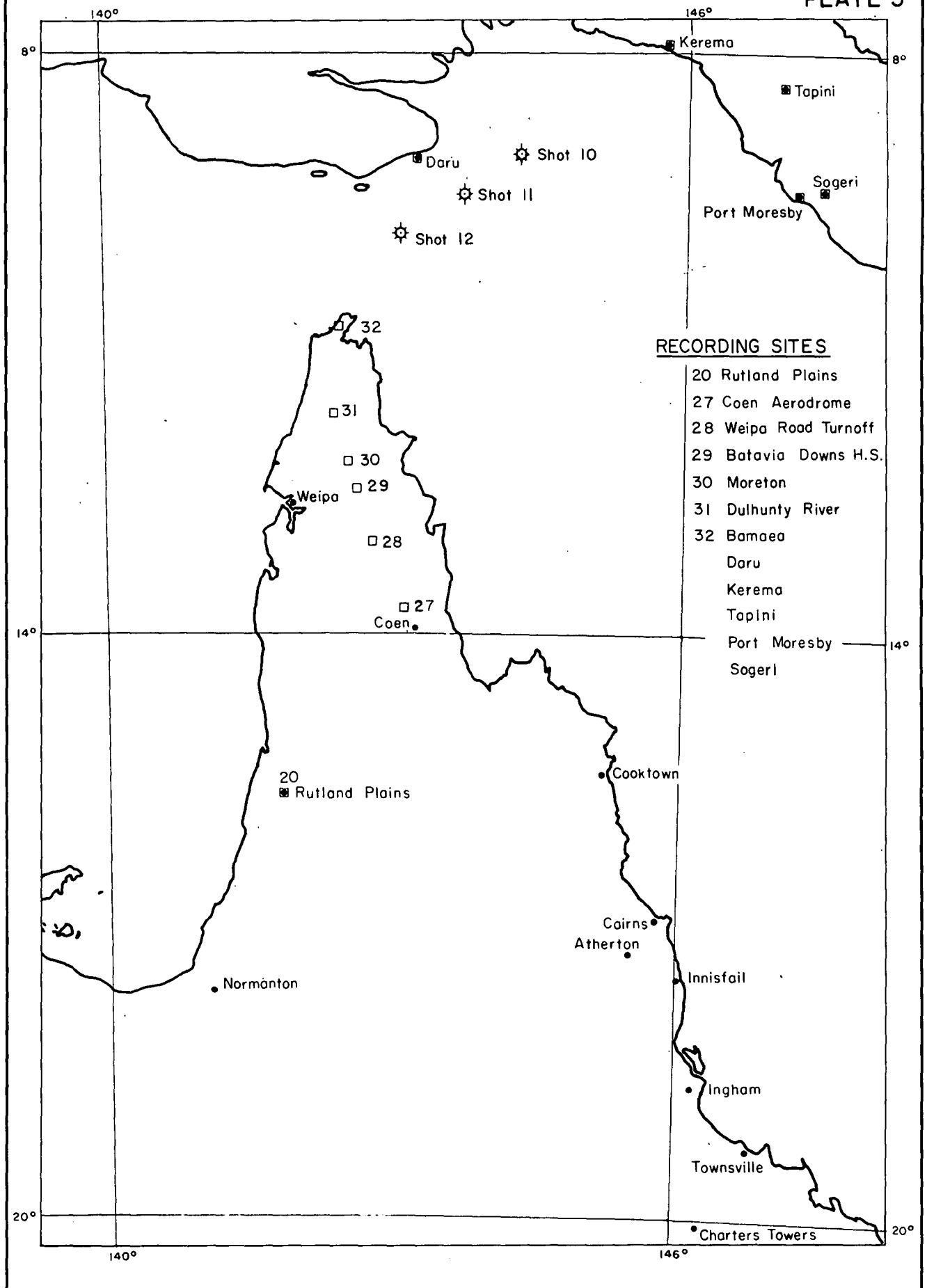
Miles 100 0 100 200 300 Miles

TO ACCOMPANY RECORD N°1968/14

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G 443-5

PLATE 5



GROUP C SHOTS AND RECORDING SITES

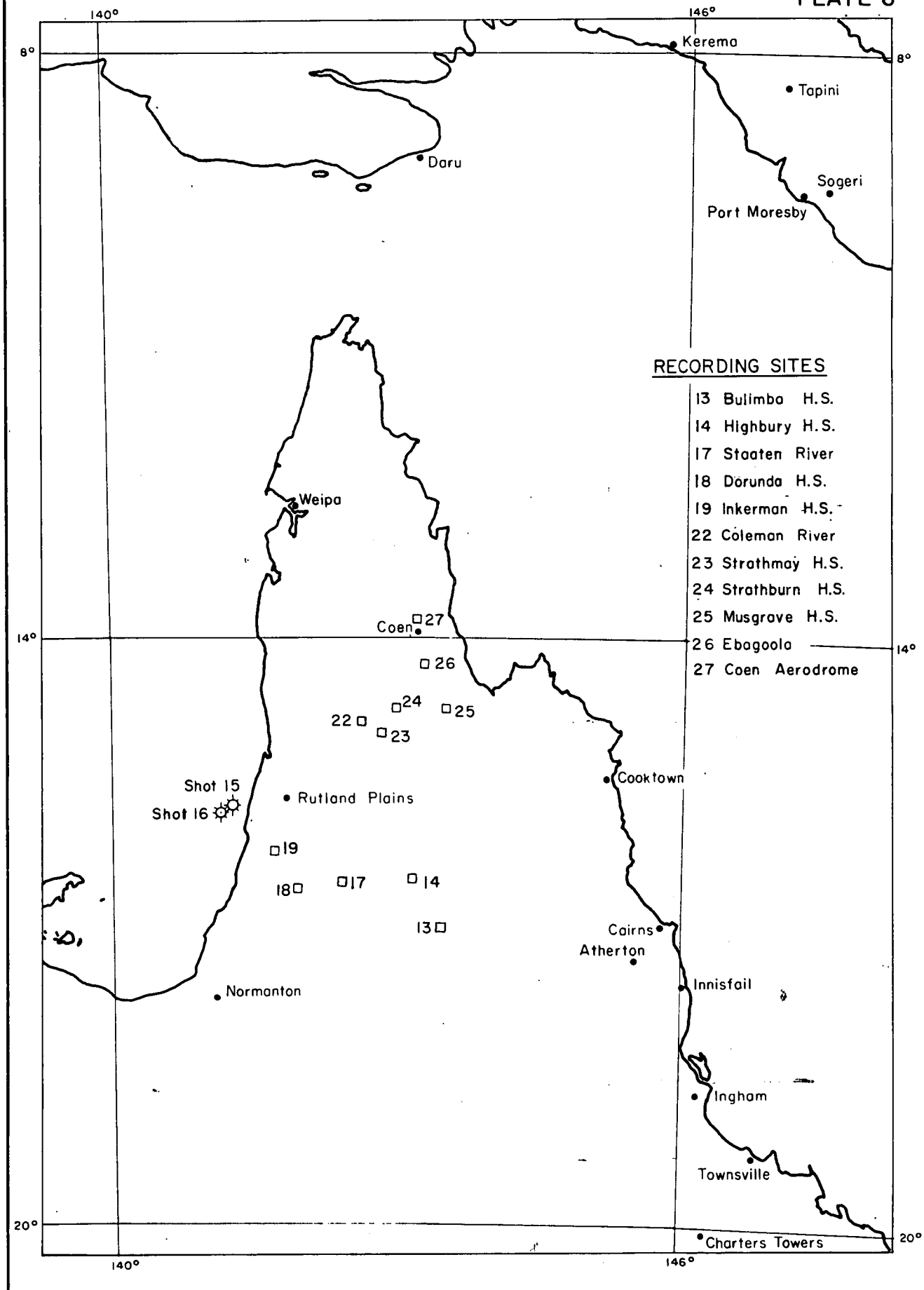
Miles 100 0 100 200 300 Miles

TO ACCOMPANY RECORD N°1968/14

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G 443 – 4

PLATE 6



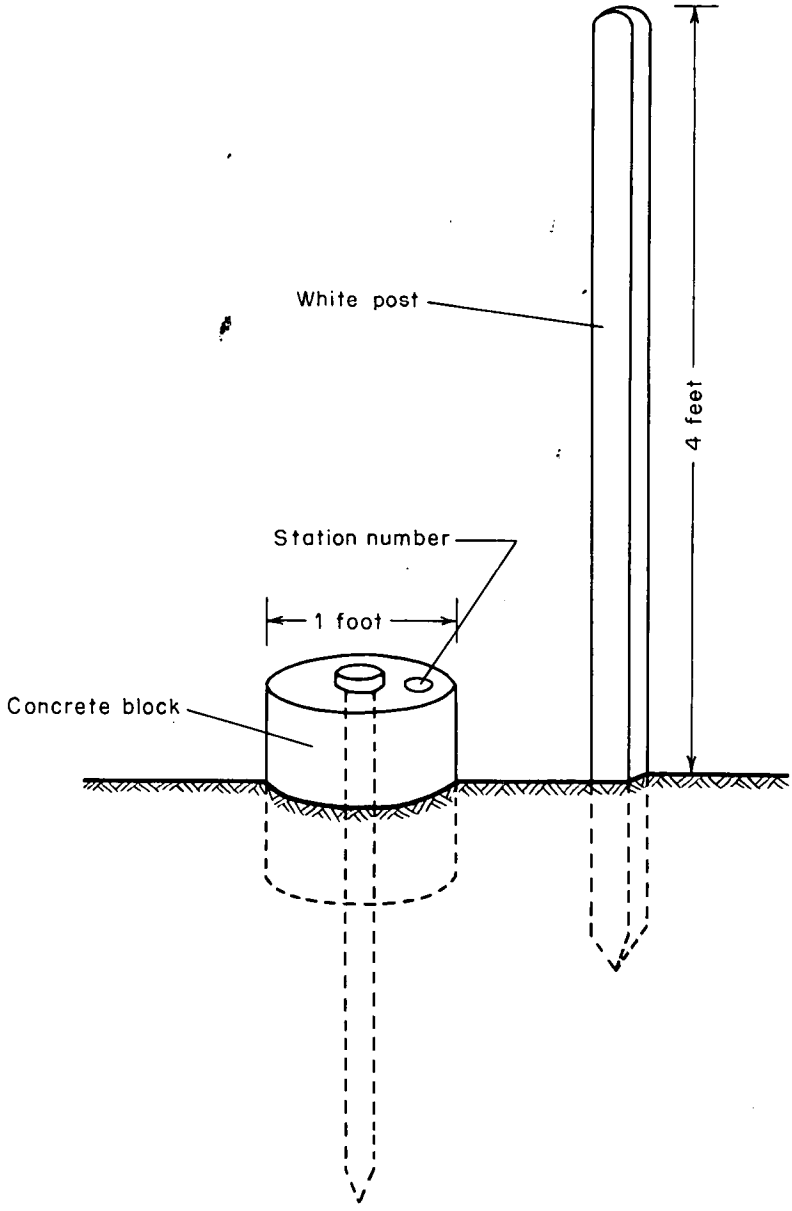
GROUP D SHOTS AND RECORDING SITES

Miles 100 0 100 200 300 Miles

TO ACCOMPANY RECORD N° 1968/14

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G 443–3

PLATE 7



SKETCH OF LANDS DEPARTMENT BENCH MARK

TO ACCOMPANY RECORD N° 1968/14

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G443-1

OPERATION CRUMP, QLD, 1966