British Geological Survey

TECHNICAL REPORT WC/94/28R
Overseas Geology Series

APPLICATION OF THE SEISMIC REFRACTION METHOD TO THE STUDY OF BASEMENT ROCK AQUIFERS IN S E ZIMBABWE (appendices 1 - 5)

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Keyworth, Nottingham, British Geological Survey, 1994

APPENDIX 1

DIARY

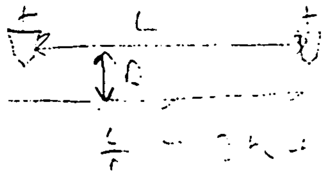
11 February	To London (Heathrow) where caught flight BA053 to Harare, Zimbabwe.
12 February	Arrived in Harare where collected hire vehicle to the airport. This proved to have defective shock absorbers.
13 February	In Harare.
14 February	Obtained a replacement hire vehicle at Echo Car Hire in Harare. Assisted Mr P Rastall acquire a suitable Landrover for field work at Chiredzi. His own vehicle had not been repaired therefore repaired Landrover 80TCE333 at the Ministry. Drove both vehicles to Chiredzi where booked into the Tambuti Lodge Motel.
15 February	Met project staff at the Research Station. Met Duncan Thompson and John Butterworth at Duncan's house in Triangle. Discussed the content of the geophysical study and collected necessary data and maps.
16 February	With Duncan to the Tamwa project area where was shown the operation of the ABEM seismic equipment. Employed Philip to fire shots using the hammer/plate system. Undertook profiles TAM1 and TAM2. Returned to Chiredzi.
17 February	To Tamwa where with Philip undertook profiles TAM3, TAM4 and TAM5. Returned to Chiredzi.
18 February	To Tamwa where with Philip undertook profiles TAM6, TAM7 and TAM8. Returned to Chiredzi.
19 February	Assessed data.
20 February	Sunday.
21 February	To Tamwa where with Philip undertook profiles TAM9 and TAM10. Delayed by rain. Returned to Chiredzi.
22 Feb	To Tamwa where with Philip undertook profiles TAM11, TAM12 and TAM13. Returned to Chiredzi
23 February	To Tamwa where with Philip undertook profiles TAM14, TAM15 and TAM16. Returned to Chiredzi.
24 February	To Tamwa where told that Philip and other project personnel were attending a funeral and would not be available tomorrow either. Returned to Chiredzi where assisted Peter Rastall with the repair of the water swivel off his drilling rig. Visited the drill site at Dekeza school on the Zaka road. Returned to Chiredzi.

25 February	Arranged the manufacture of a 7.5 kg 8" diameter steel strike plate at Chiredzi. Discussed the project so far and the Water AID managed Bikita emergency drilling programme with Dr Chris Lovell.
26 February	Saturday.
27 February	Discussions with Dr R Herbert at Duncan's house in Triangle. Handed over hire vehicle to Dr Herbert for him to drive back to Harare.
28 February	In Land Rover 80TCE333 drove to Triangle for further discussions with Dr Herbert. Drove from there to Tamwa where with Philip attempted a profile at HDW23 but equipment u/s. Returned to Triangle where discussed problem with Duncan. Drove to Chiredzi to effect repairs to trigger cable.
1 March	At the Research Station obtained photocopies of aerial photographs and maps of the Tamwa area. Logged geological samples from boreholes 'A' and '4' drilled adjacent to the collector well at Tamwa. Collected repaired trigger cable.
2 March	Drove to Tamwa where with Philip undertook profiles TAM17, TAM18 and TAM19. Returned to Chiredzi. Discussed the collection of water samples at Tamwa with Duncan.
3 March	Drove to Tamwa where with Philip undertook profiles TAM20, TAM21 and TAM22. Returned to Chiredzi.
4 March	Drove to Tamwa where with Philip obtained water samples from all hand-dug wells in the monitoring system except the collector well and an adjacent well, run out of sample bottles. Returned to Chiredzi.
5 March	Visited the Middle Sabi Irrigation Project where boreholes have recently been installed in thick alluvial deposits to provide alternative sources of groundwater during periods of low flow along the Sabi River.
6 March	Analysis of seismic data.
7 March	Discussed results of project with Chris Lovell. Arrange transport for the coming week. Further analysis of data.
8 March	Report writing at Chiredzi research station.
9 March	Maintenance on Land Rover 333 and additional report writing.
10 March	Conducted two seismic refraction profiles adjacent to the Chiredzi research station collector well. The first profile utilised a 43.5 kg weight and steel plate as an energy source while for the second a 14 kg hammer and steel plate were used.

11 March	Drove via research station to Triangle where returned seismic refraction survey equipment to Duncan Thompson. Drove via Masvingo to Harare for discussions with Mr Marcus Sharpe.
12 March	Met Mr Charles Bachelor at Harare Airport where handed over landrover 333. Departed from Harare on flight BA052 with water samples for London (Heathrow).
13 March	Arrived at London (Heathrow) just before the IRA mortar attack. Driven back to Oxford.

APPENDIX 2

ABEM MINILOC SEISMIC SYSTEM INSTRUCTION MANUAL



ABEM

Instruction Manual

Preliminary version 91a

Issued by: ABEM AB, Box 20086, S-161 02 Bromma, Stockholm Sweden.
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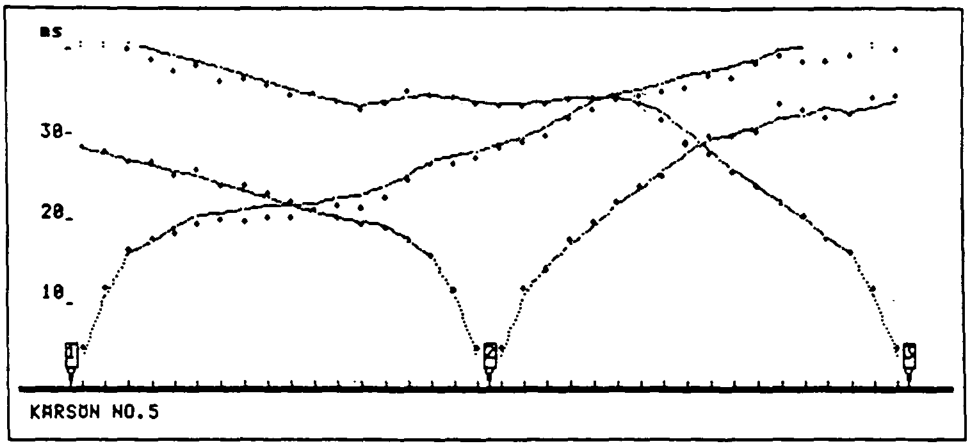
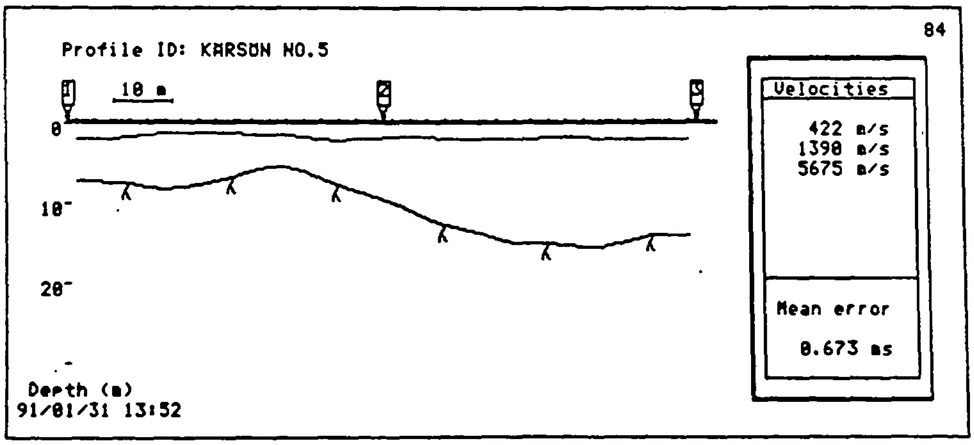
ABEM MINILOC Seismic System





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ABEM Printed Matter No 93063

Table of Contents

1 Introduction

This Instruction Manual covers operation, maintenance and, where appropriate, reduction of MINILOC[1] seismic data. A careful study of this manual is recommended before starting to work with the equipment.

This manual is preliminary; the final version will be submitted as soon as it is ready.

ABEM instruments are carefully checked at all stages of production and are thoroughly tested before leaving our factory. They should provide many years of satisfactory service if handled and maintained according to the instructions given in this manual.

ABEM will be pleased to receive occasional reports from you concerning your use of and experience with the equipment. We also welcome your comments on the contents and usefulness of this manual. When writing please include the instrument type and serial number.

In view of our policy of progressive development, we reserve the right to alter specifications without prior notice.

1.1 Unpacking and inspecting

Use great care when unpacking the instrument. Check the contents of the box or crate against the packing list that is included. Inspect the instrument case for any damage that may have occurred because of rough handling during shipment.

Shipping damage claims

File any claim for shipping damage with the carrier immediately after discovery of the damage and before the equipment is put into use. Forward a full report to ABEM, making certain to include the ABEM delivery number, instrument type and serial number.

All packing materials should be carefully preserved for future re-shipment, should this become necessary.

1.2 Warranty

ABEM warrants each instrument manufactured by them to be free from defects in material and workmanship. ABEM's liability under this warranty is limited in accordance with the terms of Clause 9 of General Conditions for the Supply of Plant and Machinery for export prepared under the auspices of the United Nations Economic Commission for Europe, Geneva, March 1953. It covers the servicing and adjusting of any defective parts (except fuses and batteries). The Warranty is effective for twelve (12) months after the date of Bill of Lading or other delivery document issued to the original purchaser, provided that the instrument is returned carriage paid to ABEM, and is shown to ABEM's satisfaction

1 MINILOC is a registered trade mark of ABEM AB.

to be defective. If the fault has been caused by misuse or abnormal conditions, repairs will be invoiced at cost.

Should a fault occur that is not correctable on site, please send full details to ABEM. It is essential that instrument type and serial number are included and, if possible, the original ABEM delivery number. On receipt of this information, disposition instructions will be sent by return. Freight to ABEM must be pre-paid. For damage or repairs outside the terms of the Warranty, ABEM will submit an estimate before putting the work in hand.

ABEM assumes no responsibility for steps that are either taken or not taken as the result of decisions based on the results of measurements taken with instruments made by ABEM or calculations based on software delivered by ABEM.

Be sure to fill in the warranty registration card (included with the equipment) correctly and return it to ABEM promptly. This will help us process any claims that may be made under the warranty.

1.3 Repacking and shipping

ABEM packing is designed for the instruments concerned and should be used whenever shipping becomes necessary. If original packing materials are unavailable, pack the instrument in a wooden box that is large enough to allow some 80 mm of shock absorbing material to be placed all around the instrument. This includes top, bottom and all sides. Never use shredded fibers, paper or wood wool, as these materials tend to pack down and permit the instrument to move inside its packing box.

Do not return instruments to ABEM until shipping instructions have been received from ABEM.

2 Instrument Description

The ABEM MINILOC is a three channel seismograph utilizing the principle of reciprocity to conduct shallow refraction seismics. All necessary software for processing and interpretation is build into the instrument, and the results are presented on the LCD display or on an optional printer. All data can be transferred to a PC computer for storage or further processing.

The MINILOC is convenient also for shallow reflection seismic studies as well as for vibration studies.

The basic system consists of:

- a MINILOC basic unit (seismograph)
- three geophones
- two marked geophone cables (each approx. 60 m long) with connectors
- one geophone cable for the center geophone (approx. 5 m long)
- one remote control unit RCU
- one connection cable for remote control unit (approx. 60 m long)
- a battery charger
- a tools and spare kit
- a documentation kit (including communication software)
- a printer connection cable (option)

Fig 2.1. The MINILOC equipment

- a RS232 communication cable for PC (option)
- a sledge hammer (option)
- a shock plate (option)
- UBC Universal Battery Charger (option)

2.1 Handling the Program

The MINILOC instrument is completely controlled via the menu based program. When you turn on the instrument, information about the program version number is presented before the main menu appears.

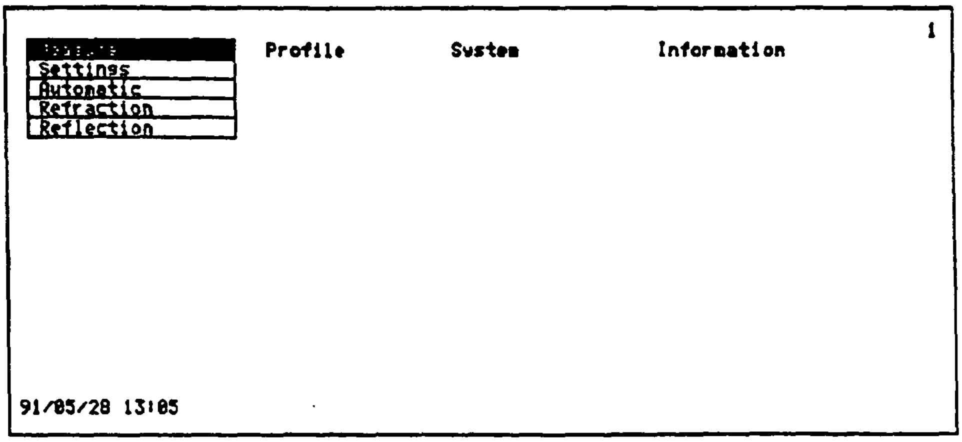


Fig 2-3. The MINILOC main menu after turning on the MINILOC.

To move between the four main items (Measure, Profile, System and Information) use the left and right arrow keys. To move up and down for selecting an option, use the up and down arrow keys (the scroll keys will work also).

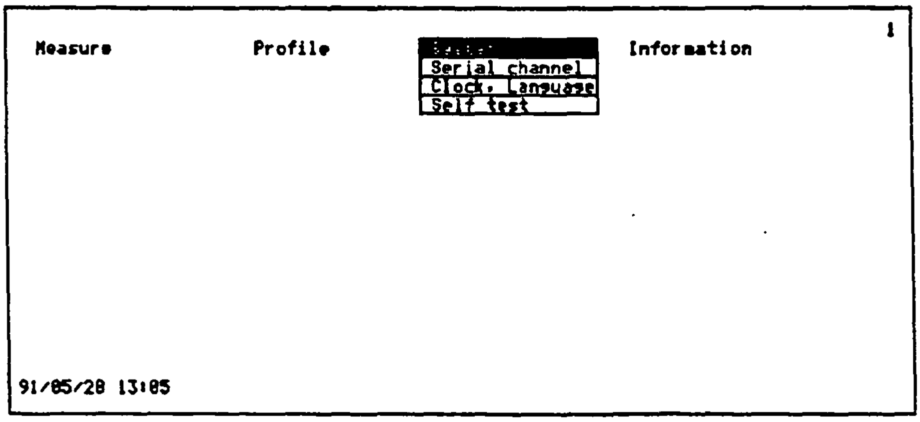


Fig 2-2. The SYSTEM choises in the Main menu.

>> Remember, that the MENU key will bring you directly to the main menu from any location in the program. Furthermore, many of the menus can be reached directly from the main menu simply by typing its number, given in the upper right corner of the display. For example, type 51 to go to directly to the data presentation menu.

The MEASURE and PROFILE choices are described in section 3. The SYSTEM choice bring up the menu:

The option *SERIAL CHANNEL* gives the possibility to set the parameters for serial communication with the PC computer (baud rate, parity etc).

CLOCK, LANGUAGE gives the possibility to set the internal clock and change between the two build-in languages (e.g. English / Swedish).

SELF TEST brings up the self test menu (no 4) in which the voltage from the A/D converters can be displayed directly. The most useful function is the VOLTAGE TEST option, in which the battery voltage is displayed.

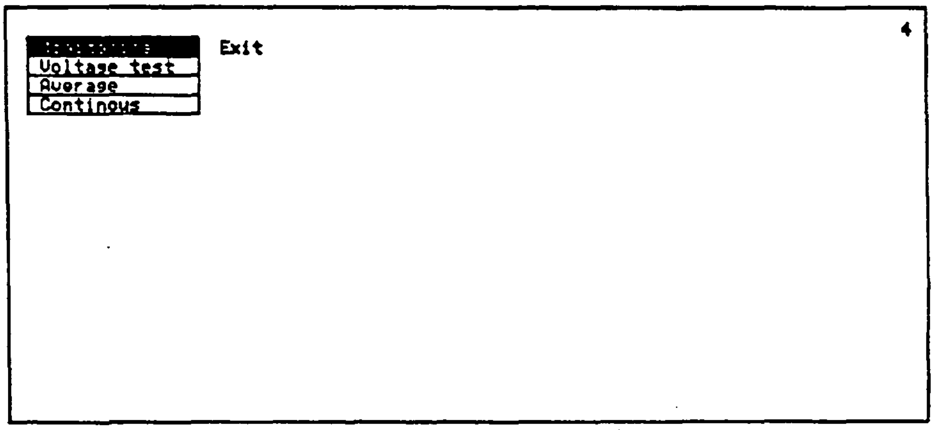


Fig 2-4. The SELF TEST menu with the three choises for voltage monitoring. Select VOLTAGE TEST to display the battery voltage.

The rightmost choice *INFORMATION* presents the MINILOC program version number plus the telephone numbers and address to ABEM.

2.2 Battery

The MINILOC is powered by a build-in 12V NiCd battery pack. The instrument can run also from an external 12V battery pack or a car battery via an optional cable (9136 0000 82).

2.2.1 Ni-Cd Battery Pack

Modern field instruments need a reliable source of power. Today, this can best be provided by sealed rechargeable nickel-cadmium (Ni-Cd) batteries. They can be discharged and recharged 1000 times or more and they can be overcharged continuously (no time limit when charged with the MINILOC battery charger or the ABEM Universal Battery Charger).

External battery

The MINILOC can be connected to an external 12V battery (e.g. a car battery) with an optional cable. The use of an external battery is indicated by red light from the lamp in the upper right of the panel.

Storage

There is no limit on storage time. Ni-Cd batteries can be stored for years, either charged or discharged. Stored batteries lose their charge (self-discharge) gradually, and this takes place more rapidly at higher ambient temperatures. However, even if a battery loses all of its charge during storage, satisfactory operation can be restored after one or two charge/discharge cycles. During storage, batteries should be in the open circuit condition. Batteries can be stored at ambient temperatures ranging from -40°C to +65°C.

Safety precautions

- DO NOT destroy or overheat a Ni-Cd battery (e.g., do not burn it in an oven!). It may burst or release toxic materials.
- DO NOT short circuit the battery since this will result in high discharge currents that cause dangerous heating.

Since, in sealed Ni-Cd batteries, (used in ABEM instruments) the battery pack and the cells inside it are tightly sealed, you will not normally come into contact with the electrolyte. You should nonetheless be aware that the electrolyte used in both sealed and vented Ni-Cd batteries is potassium hydroxide. If you should get it in your eye, even a small amount can cause serious injury. Immediate flushing with water for 15 minutes plus follow-up medical attention is absolutely necessary. If the electrolyte gets on your skin, use vinegar or some other mild acid for neutralization.

Finally, it should be remembered that the cadmium in an Ni-Cd battery is a toxic metallic element that should not be disposed of in the usual way, since it represents a serious threat to the environment.

2.2.2 MINILOC battery charger

The standard MINILOC battery charger provides a constant charging current of about 400mA with 12V output voltage. When the battery is fully charged the current drops to a minimum. The charger is designed for 220V, 50Hz AC input or 110V, 60Hz (depending on specifications).

The charging time for a completely discharged battery is approximately 14-16 hours.

2.2.3 UBC Universal Battery Charger

The UBC is ordered separately (order code 9133 0012 90).

Input

The UBC accepts the following power inputs, and permits you to change from one to another without troublesome rewiring or relinking:

- 12 V batteries (vehicle batteries)
- 24 V batteries
- 110 V, 60 Hz mains
- 220 V, 50 Hz mains

The full input ranges are 10-30 V DC and 100-240 V AC, 47-63 Hz.

Output

The UBC is especially convenient for charging ABEM instruments. The standard output cables are provided with connectors compatible with the battery packs used in ABEM instruments.

The UBC can:

- Charge one 12V battery pack (in the MINILOC for example)
- Charge, simultaneously, two 12V battery packs (e.g. the MINILOC battery and the external battery)
- Charge one 30V battery pack

WARNING: Do not charge 2 completely drained batteries simultaneously!

Note that you should never try to charge two batteries in parallel from the same outlet.

Note also that your UBC charger is not waterproof. If you used it outdoors, rainwater can accumulate on top and leak into the circuitry.

2.2.4 Charging Instructions

An ancillary 230 V source is therefore required for up to 10 hours per night – either a generator (requires long time to run a small petrol engined generator [illegible] 2) or a mains supply – limits the location of a field area – travel time etc. limits mobility.

Charging times

Both the MINILOC charger and the UBC both provides what is known as an overnight charge (slow charge). This charging rate (constant current of about 400 mA) is high enough to charge a fully discharged battery in 14 to 16 hours. However, in most cases, the battery is not fully discharged and the time needed to reach full charge will thus be shorter. 10 hours is usually sufficient. Charging longer than overnight (overcharging) should be avoided since it wastes energy.

>> Check regularly the battery voltage (from the *SYSTEM* and *VOLTAGE TEST* menu. When the voltage is around 12.5V the battery is fully charged. When it drops below around 11V it is time for charging. This is indicated by the lamp in the upper right corner of the panel: when power for only a short time is left the lamp will start blinking.

By regularly checking the voltage you will learn to know the behavior of the battery.

Charging one or two 12 V battery packs with the UBC

Connect the battery pack(s) to the battery charger output(s) via output cable(s) 9136 0000 81. If the charger is to be connected to the mains (100-240 V AC, 47-63 Hz), use input cable no 9139 7100 31. If the charger is to be connected to a vehicle battery or any other DC supply (minimum 10 V, maximum 30 V), use input cable No.9136 0000 82. Connect the black clip to the negative (-) terminal. Since there is an indicator lamp (light-emitting diode) for each of the two charger outputs, you can easily see whether or not charging is proceeding properly.

Temperature limits

Your Ni-Cd battery can be discharged and charged continuously within the cell temperature limits set forth below:

Discharge -20°C to +65°C

Charge +5°C to +65°C

Note that the cell temperature is defined as the temperature measured directly on the cell casing, and thus differs from the ambient temperature. However, for practical purposes, the cell temperature and ambient temperature can be considered the same during discharge at the rates encountered in geophysical instruments, since no significant amounts of heat are generated within the battery. This also applies to charging at the rate provided by as well the MINILOC charger and the UBC. But there is a difference during overcharging, which should not be carried out above 50^{0}C.

2.3 Geophones

In the standard MINILOC equipment three 14Hz geophones are supplied. They are coupled with a two-conductor connector to the standard cable set (see below). Any other type of geophones can be used in stead of the standard geophones. Upon special order other type of geophones can be delivered, e.g. 30Hz or 50Hz for reflection surveys. Also a three-component 4.5Hz geophone is available for special seismic studies, e.g. vibration.

The supplied 14Hz geophones are well suited for refraction seismics. The resonance frequency of the geophones is 14Hz, and the sensitivity is almost constant in the frequency range 14Hz to 500Hz. The useful signal in shallow refraction seismics is typically in the frequency range 40Hz to 100Hz. This means that low-frequency disturbances like traffic noise and most wind noise are eliminated because the geophones acts as low-cut filters. In noisy areas it is however recommended to set the analog low-cut filters in the MINILOC to e.g. 35Hz, for improved signal quality.

It is very important to place the geophones vertically and in good contact with the ground. When the uppermost part of the ground surface consist of loose or swampy material the ground coupling can be poor, giving a bad data quality. It is therefore recommended always to bury the geophone in a small hole (say, 20cm deep) and cover it with soil. This will improve the ground coupling and drastically reduce the noise. Especially in rainy weather it is strongly recommended to bury the geophones, because the raindrops falling on a geophone will generate strong noise signals.

2.4 Cable set

The standard cable set consist of two 60m long marked cables (for the outer geophones, called G1 and G3) plus a 4m cable for the center geophone called G2. The long cables are marked every 3m with the numbers 1 to 18 and 19 to 36 for geophone G1 and G3 respectively. The cables are connected to the MINILOC instrument with a 4-pin "KPT" connector, and to the geophones with special sealed two-conductor connectors. **Please remember to use the connector lock on the cables and on the geophones when not in use.**

2.5 Energy source

The standard method of producing seismic waves in shallow investigations is a sledge hammer. Other seismic signal sources for shallow depths are explosives, gas exploders, falling weights and shot guns.

All these sources produce a short sudden pulse and the decision of which to use depends only on the type of survey and of course as mentioned before economy and safety.

A sledge hammer produces sufficient signal strength for reflection seismics down to 50-75 m, and for refraction seismics up to 100-150 m distance. For greater depth or separation a heavy falling weight or explosives are recommended. For very shallow applications a shot gun will often provide sufficient energy.

The main frequency of a sledge hammer pulse is normally around 50-100 Hz, on hard ground up to 150Hz. However, due to the inherent low-pass filtering in the ground, the lower frequencies will normally be dominating. A shot gun produces a signal of higher frequency, and a falling weight a signal of lower frequency.

A convenient energy source for shallow refraction studies is a heavy sledge hammer, approximately 8 kg (the optional ABEM sledge hammer has order code 9138 6000 12). It is always necessary to hit a shock plate, in order to get as much energy as possible into the ground. The most convenient shock plate is the ABEM rubber plate (delivered optionally, order no 9133 0010 18). It will stand for many years of extensive use, and it will not generate any hazardous sound as e.g. a steel plate. The frequency of the shock wave generated by a hammer and a rubber plate will normally be in the range 30 to 60 Hz. A shock plate made of steel or aluminum will in general produce a signal of higher frequency.

2.6 Remote Control Unit

The remote controller unit (RCU) serves two purposes in the MINILOC system:

1 During data collection along the measuring profile, the MINILOC is controlled from the RCU. The top of the RCU contains a two-digit liquid crystal display (LCD) screen, showing the actual shot point number (1 - 36). On each side of the LCD are located two lamps (light-emitting diodes, LED) green to the right and red to the left. Whenever the MINILOC is on, the green lamp lights, and the LCD display shows the number of the next shot point. When ready for shooting the operator arms the MINILOC by pressing the pushbutton. This causes the red lamp to light instead of the green. Now the MINILOC is waiting for the shot(s).

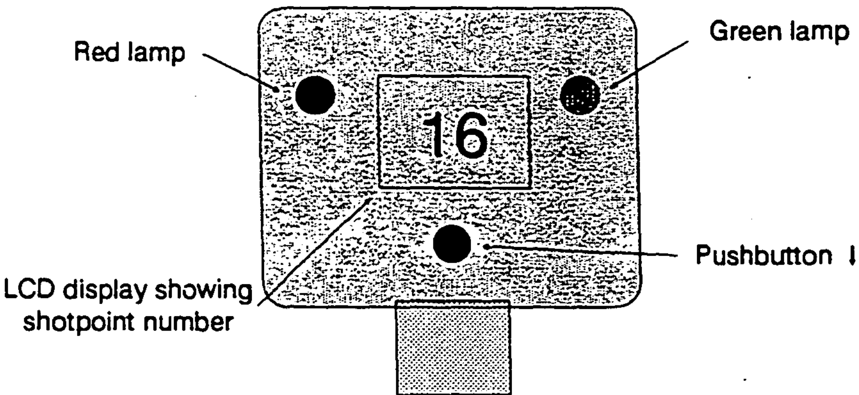


Fig 2-5. The Remote Control Unit (Top view)

2 The RCU contains a build-in trigger, which accurately detects when the shot is fired (I.e. when the hammer hits the shock plate). The trigger actually consists of a piezo-electric crystal. When the RCU trigs, the MINILOC starts collecting the data from the geophones G1, G2 and G3. The red lamp is off for a short time (approximately 1 sec), while the MINILOC checks the data quality and performs the stacking. When the MINILOC has finished a shot point (either because the maximum number of stackings has been performed or because good data quality allowed the system to stop earlier) the green lamp lights, and the number of the next shot point is displayed on the LCD.

The RCU cable is not robust enough. The cable is not armoured or reinforced. It stretches easily which as resulted in the breaking of the internal very thin and flimsy copper conducting wires. The connectors tend to jam easily in dusty conditions – become very difficult to connect and disconnect.

3 Refraction data collection and interpretation

In the following we will describe the MINILOC measuring technique used to perform refraction seismics. The only difference compared with "conventional" refraction seismics is that the shot points and geophone points are reversed. This is possible due to the principle of reciprocity, which states that "the source and receiver can be interchanged without affecting the result".

3.1 The standard layout.

In the MINILOC standard layout the three geophones are placed with 54 m separation. The MINILOC instrument is placed within a few meters from the centrum geophone. The two outer geophones (called G1 and G3) are connected with the marked cables. The cable connecting geophone G1 is marked with the numbers 1 through 18 and the cable connecting geophone G3 with the numbers 19 through 36. The marks - indicating the shot points - are located with 3 m separation, and the two outer geophones are placed 1.5m "outside" shot point 1 respectively shot point 36. This gives a total profile length of 108 m in the standard layout. The central geophone (called G2) is located in the middle between shot point 18 and 19, and is connected to the MINILOC with a five meter connection cable. The standard layout is suitable for delineating targets down to a maximum depth of 20 to 30 meters. Whenever you choose the standard layout as described above, you have to choose the option *AUTOMATIC* from the *MEASURE* menu. More about this later on.

The above layout describes the standard layout. In fact any symmetrical layout can be used. In some cases when you need greater penetration depth it is favorable to locate the outer geophones G1 and G3 at greater distance from the center, keeping the shot point separation at three meter. This is easily accomplished by using extension cables between the marked standard cables and the geophones G1 and G3. If necessary you can increase the shot point distance to e.g. 5 meters and use an ordinary measuring tape to locate the shot points. Remember, however, always to keep the layout symmetrical, i.e. keep the distance G1-G2

Extension cables were not available therefore could not increase the spread length – using the plates available the normal first arrivals at distances >100 metres would be too faint to record effectively.

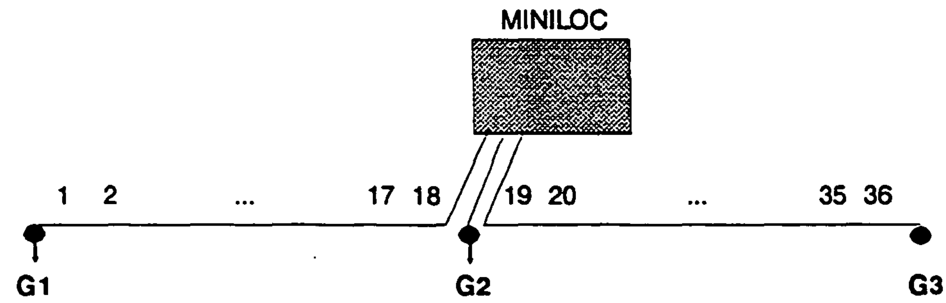


Fig 3-1. MINILOC layout with geophones G1, G2 and G3 and shotpoints 1 to 36.

equal to G2-G3, and to keep all 36 shot points in between the geophones G1 and G3. In most cases it is, however, difficult to generate enough seismic energy with the sledge hammer for larger distances than in the standard layout.

Another possibility - in the case of more shallow targets - is to decrease the shot point distance, and eventually also the geophone separation. As an example, you can use the standard geophone layout but decrease the shot point distance to only 1 m. In that case you have to place the 36 shot points starting 2 m after the cable mark "12" (which is 6 m to the left of geophone G2) up to 1 m after the cable mark "24" (6 m to the right of G2). Whenever you choose the non-standard layout you have to choose the option *REFRACTION* from the *MEASURE* menu, and specify the shot point distance and the geophone offset manually. More about the menus later.

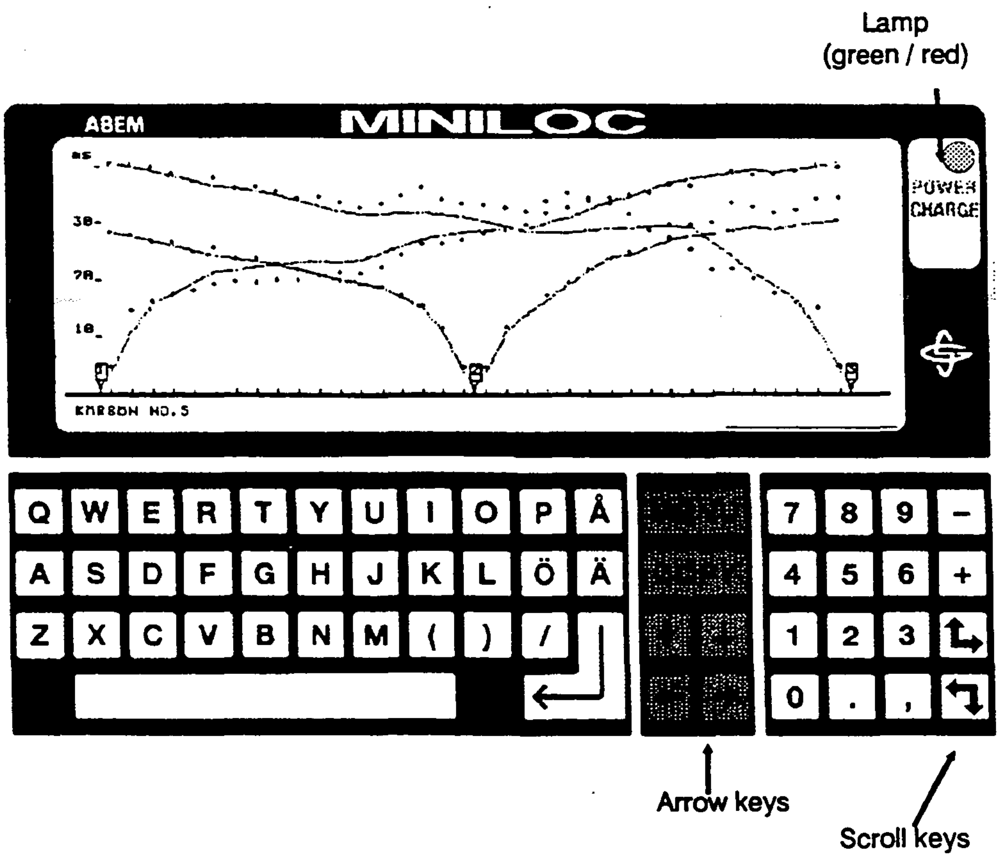


Fig 3-1. The MINILOC keyboard with the graphic LCD display.

3.2 Setting up the MINILOC instrument.

When all three geophones are connected it is time to turn on the MINILOC. The program starts automatically and presents the main menu. Please note that all menus are numbered; the number is always shown in the upper right corner of the display. The main menu has number 1.

The MINILOC screen.

The left part of the keyboard contains the conventional alphanumerical keys. In the middle the MENU, PRINT and ARROW keys are located. The MENU key will always bring the program to the main menu (1). PRINT will make a screen-copy of the content of the display. With the arrow keys you can move between different options in the menus.

The rightmost part of the keyboard contains the numerical keys and the scroll keys. The scroll keys are used to scroll the data displays up and down, but can be used also to move between different options in some of the menus.

The + and - keys are used to move the time markers in some of the data display menus. light/dark on screen.

Instrument setup

In menu 1 choose the option *AUTOMATIC* if you intend to use the standard layout, otherwise choose the option *REFRACTION*. A menu option is chosen by moving the cursor (the black horizontal bar) with the arrow keys to the decided option and then pressing the ENTER key.

If you choose *REFRACTION* you have to specify some measuring parameters, e.g. shot point spacing and geophone offset.

To summarize the steps to set up the instrumentation for refraction measurements:

1 Choose a suitable profile where you can place the geophones G1, G2 and G3 at undisturbed and suitable locations (not on a highway nor in a river).

2 Put a stick in the ground to identify the centrum of the profile, and place the MINILOC within a few meters from the centrum.

3 Connect geophone cable 1 (marked with the numbers 1 - 18) to the MINILOC connector CH 1 and secure the cable with a stick in the loop.

4 Bring one geophone and a stick together with the cable to geophone position G1, identified by the loop 1.5 m "outside" point number "1" on the cable.

5 Stretch the cable and secure it with the stick in the loop.

6 Place the geophone close to the loop and connect it to the cable.

7 Repeat step 3 through 6 with cable 2 (marked with the numbers 19 - 36). Use connector CH 3 on the MINILOC.

8 Place the third geophone at position G2, i.e. very close to the centrum stick. Connect it to the MINILOC connector CH 2 using the supplied 5 m cable.

9 Connect the remote control cable to the MINILOC and go to shot point 1 with the remote control cable drum, the remote control unit, the sledge hammer and the shock plate.

3.3 The Geophones, Hammer and Remote Control Unit

Geophones

It is very important to place the geophones vertically and in good contact with the ground. When the uppermost part of the ground surface consist of loose or swampy material the ground coupling can be poor, giving a bad data quality. It is therefore recommended always to bury the geophone in a small hole (say, 20 cm deep) and cover it with soil. This will improve the ground coupling and drastically reduce the noise. Especially in rainy weather it is strongly recommended to bury the geophones, because the raindrops falling on a geophone will generate strong noise signals.

Because only three geophones are used in the MINILOC method, the time spend on safely placing them is short compared to the total measuring time.

Take care not to place the geophones in direct contact with a stretched cable: in some cases a sound wave will travel through the cable and create a false signal in the geophone (too early arrival).

Hammer

Remember to place the shock plate as close as possible to the selected shot position (the cable mark). However, ensure that the cables are not in touch with the shock plate, otherwise a sound wave can be transmitted through the cable and produce a disturbing signal in one of the geophones!

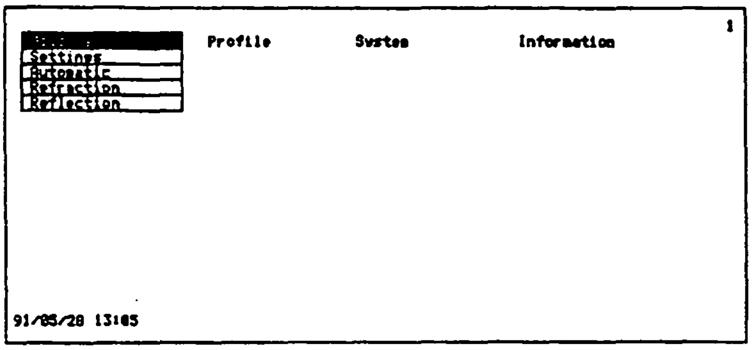
Be sure that the shock plate is lying stable on the ground; to stabilize it, you can hit it once with the hammer before starting measuring. Normally 3 to 5 shots are needed at each shot point (more about stacking later on). To achieve a good data quality it is very important to transmit as much energy as possible into the ground. After some time you will gain experience in how to use the hammer in the most effective way without becoming tired. The rubber shock plate will - due to its elastic properties - when you hit it create an upward directed force on the hammer, and in this way help you to lift the hammer for the next shot. The time between the stackings on the MINILOC is short enough (approximately one second) to allow you to "shoot" almost continuously with the hammer.

Remote Control

The Remote Control Unit must be placed rather close to the shock plate (the shot point), a distance of approximately 20cm is convenient. It is very important to keep this separation almost constant at the different shot points, otherwise a timing error is introduced. The velocity in the uppermost part of the soil is typically about the same as in air, i.e. about 330m/s. This implies that the time delay introduced by the offset between the shock plate and the Remote Control Unit will be around 0.2/330*1000 = 0.6 msec. On the contrary, the RCU should of course not be placed so close to the shock plate that there is any risk to damage it with the hammer!

3.4 The MINILOC program

Turn on the MINILOC with the main power switch on the back panel. The green lamp on the front panel will light, and the main menu will appear on the screen.



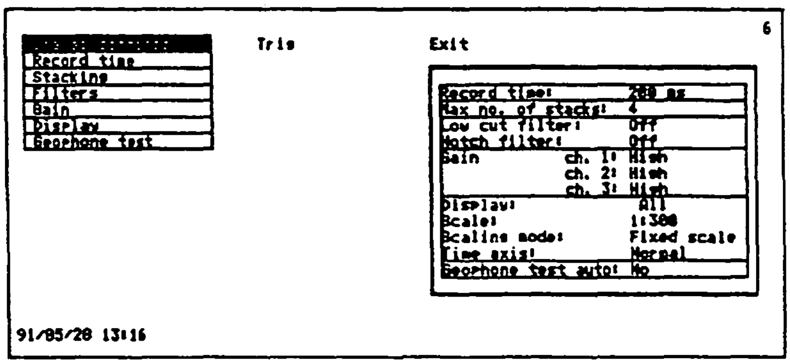
3.4.1 Setting up for measuring

The main menu (numbered "1" in the upper right corner) contains four choices. Before starting measuring, check the settings. To do this, move the cursor (black horizontal bar) to *SETTINGS* and press the ENTER key. This will bring up the settings menu (number 6), in which the number of stackings, notch filters, low-cut filters etc. are defined.

Set the number of stackings in the range 4 to 8. Experience shows that it is more favorable to hit with the hammer 3 times with high energy (strong operator) than 10 times with poor energy!

The notch filter can be activated if serious disturbances exist. In case of high low-frequency noise (traffic etc.) you can use the low-cut filter at 35Hz. Observe, that the higher frequencies (70, 105, ...) is for reflection seismics only, and should not be used in refraction seismics.

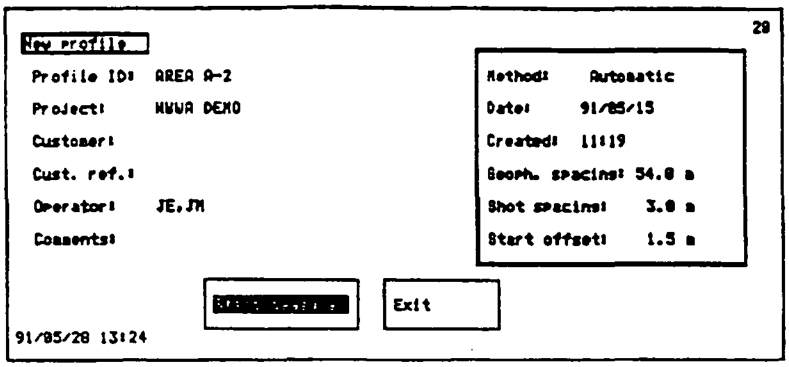
The geophone test should normally be ON. Only for special studies, using non-standard geophones, it should be turned off. In case of problems with one of the geophones, the test will give an error message.



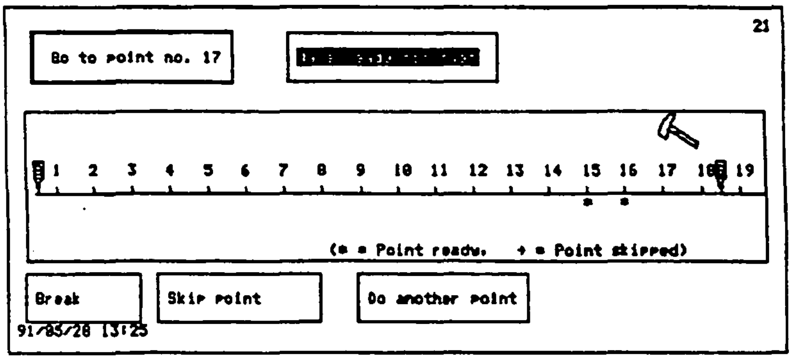
The gain is always controlled automatically in the program. However, when using the manual monitoring in the TRIG option, the gain setting is of importance. It can be set to HIGH or LOW. To the right of the display, all settings are displayed.

A useful function is the TRIG option, used to display the signal from the geophones. This can give information about the noise level and the frequency content of the noise. When you choose *TRIG* the MINILOC will simply collect the signal in the three channels and present it on the display.

Trig? Geophone Noise



When satisfied with the settings, go back to the main menu and choose *AUTOMATIC* to perform a standard survey with the standard cable. This brings up the above menu, in which necessary information about the survey is specified. The most important position is the **Profile ID** which is used for identification later on. When finished, choose the *START MEASURE* option, which will bring up the data collection menu with the hammer.

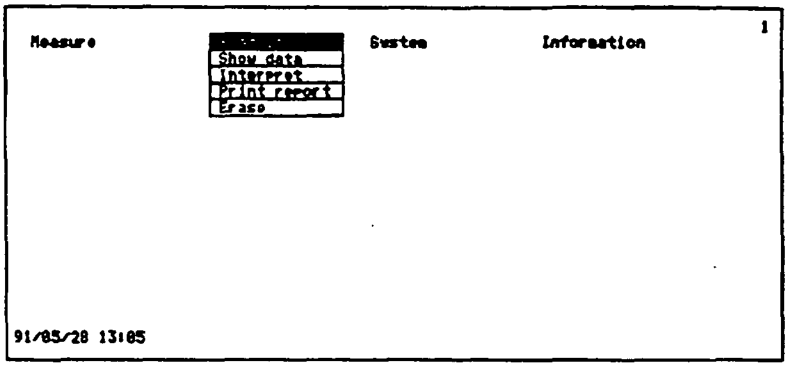


From this point the MINILOC is controlled from the Remote Control Unit (RCU), which will display the number 1. Now you can go to shotpoint 1 and start shooting.

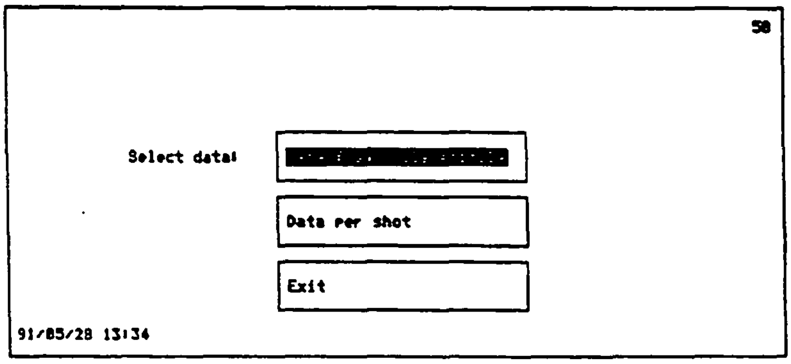
Note, that the program can be interrupted at any time during the data collection. If you want to check the data after a part of the profile, simply go to the MINILOC and choose *PROFILE* and *SHOW DATA* from the main menu (a faster way is to press the MENU key followed by 51 or 52).

If you want to skip a shotpoint, simply choose the *SKIP POINT* option. Similarly, if you observe that the data quality at one or more shotpoints are poor, choose the *DO ANOTHER POINT* option. In this way you can re-measure bad traces afterwards.

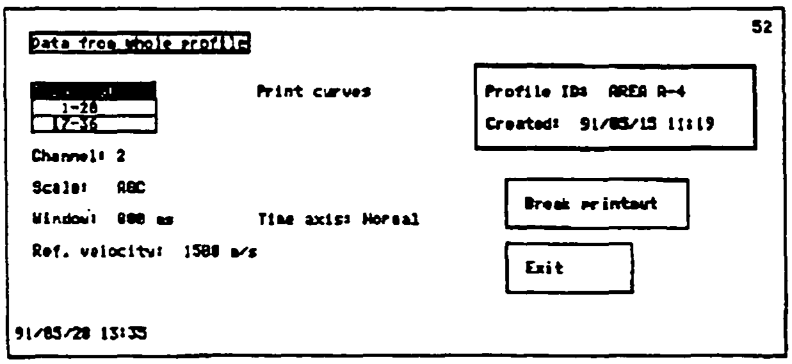
3.4.2 Data processing and display



When you have finished the profile it is time for processing. The first step is to go to *PROFILE* and choose *SHOW DATA* to check the data quality.

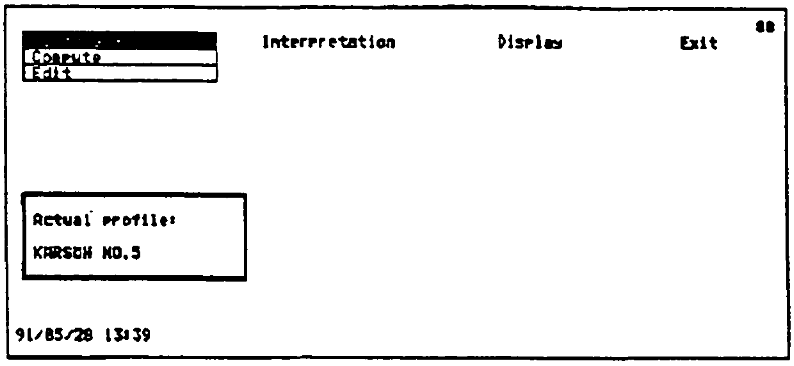


This will bring up the above menu, where you can choose between displaying data from a whole profile or data from a single shotpoint only. If you choose *DATA FROM WHOLE PROFILE* you will come to the display menu (numbered 52) where you have to specify display certain parameters. In *SHOW SHOT* you can choose between displaying trace 1-20 or trace 17-36. Print curves is for output to a printer (EPSON or IBM graphics). *CHANNEL* gives you the possibility to select between the signal from the three geophones. *SCALE* contains six choices: AGC, Normal(ized), 2, 4, 10, 50. AGC means that the signal is normalized to the signal within a certain window (set in *WINDOW*), whereas *NORMAL* means that the amplitude is normalized to the data in the whole trace.



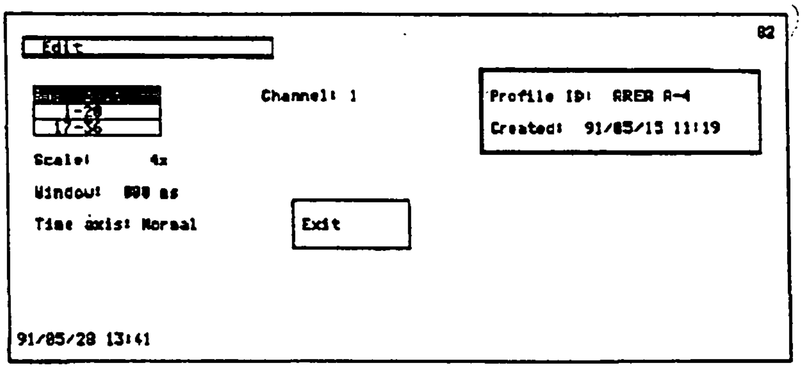
Observe, that *REF VELOCITY* is used in reflection seismics, and of no importance in refraction seismics.

The first breaks are computed automatically: go to the main menu and choose *PROFILE* followed by *INTERPRET.* This brings up the main interpretation menu (numbered 80):



Choose *FIRST BREAKS* followed by *COMPUTE*, and the program will find all the first arrival times.

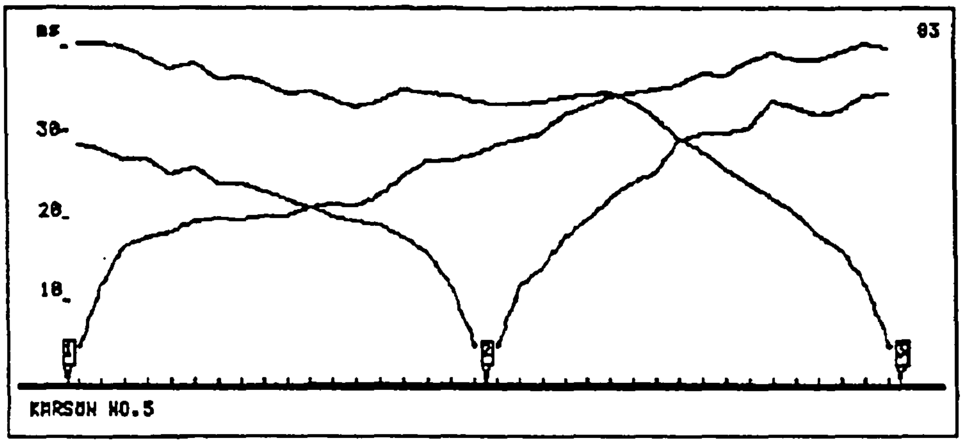
The first breaks is the essential data in refraction seismics, and they must be found with care. The build-in algorithm works fine in most cases, but a manual check of the automatic pickings is indispensable.



Therefore you have to go the EDIT menu afterwards, in order to check and adjust the arrival times. This menu is handled almost in the same way as the display menu (number 52) described above. When you choose *SHOW SHOT* and *1-20* (or *17-36*) all traces will be displayed vertically, and the computed first breaks are shown with a thin horizontal line. You can move between the traces with the arrow keys, the active trace is indicated with a black box - cursor - at the top of the trace. You can move up and down in the trace with the + and - keys. To select a new time, simply move the time axis (the dotted line) to the correct time and select *ACCEPT* (press ENTER).

Check systematically all three channels (geophones). Observe, that from the shotpoints closest to the geophones (1.5m separation) the seismic wave will arrive almost horizontally. Because the geophones only react on vertical movements, only a very small signal will - paradoxically - be detected in the geophone. In many cases therefore, the correct first break is not found at the closest distances. If you go the display menu (MENU 51) you can display a trace in the proper scale, and observe the correct first arrival. Note, that the time line is active also in menu 51, it is controlled by the + and - keys as usual.

When finished it is time to check the time-distance graph (also called the X-T curve). From the main menu choose *PROFILE, INTERPRET, DISPLAY,* and *X-T CURVES*.



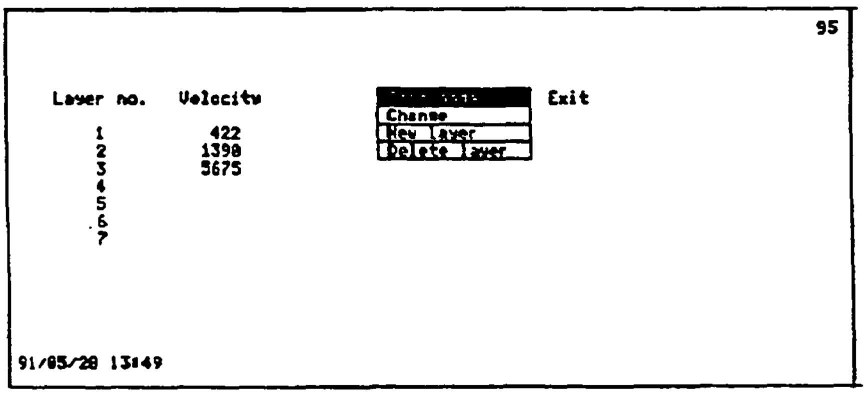
The quality of the data appears immediately in this display. the curves should be rather smooth, without any "dropouts". Whenever you observe X-T curves of dubious quality, go back to the edit menu (MENU 82) and check and adjust the data point.

An immediate measure of the data quality is indicated by the "law of parallelism". This rule states that branches from different channels should become parallel at great distances. For example, in the above display the curves from geophone G1 and G2 becomes parallel from shotpoint 27.

Observe, that the build-in interpretation program expects data from 36 shot points. This means, that if you have skipped any points during the data collection, you will have to input these data manually (in the *FIRST BREAKS, EDIT* menu).

3.4.3 Interpretation

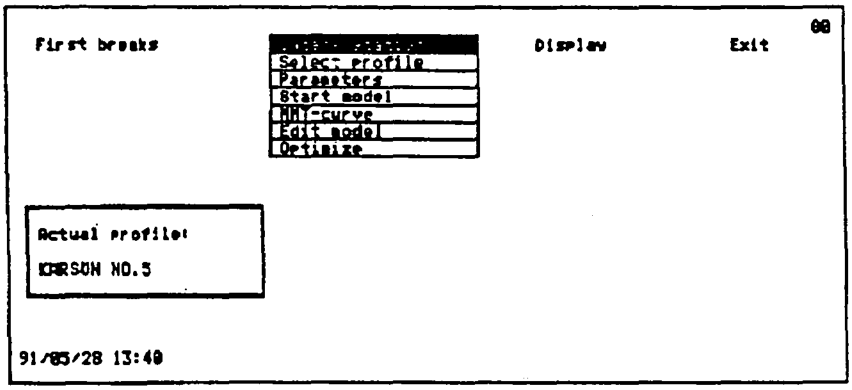
When you are sure the data quality is OK it is time to activate the automatic interpretation procedure. From the main menu, choose



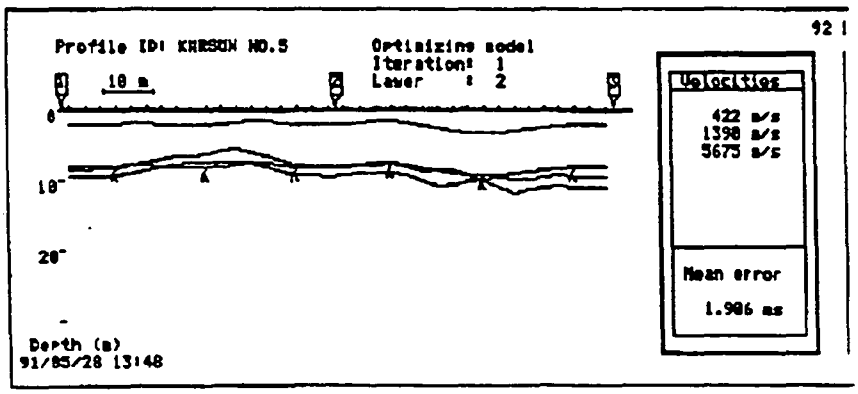
PROFILE and *INTERPRET*, and the interpretation menu will appear. Choose the option *START MODEL*, and the program will calculate appropriate velocities for a number of layers (up to 7 layers). When finished (after a few seconds) the program will display "DONE", and you can press ENTER and proceed with the *EDIT MODEL* option from the *INTERPRETATION* menu. This brings up the edit model menu, where the velocities can be changed. As an example, if you know that the saturated zone below the ground water level has a velocity of 1400m/s, then it is favorable to set the velocity of layer two to 1400m/s. You can also add or delete layers in this menu. Typical velocity values are given in the table in section 4.3.

Optimization

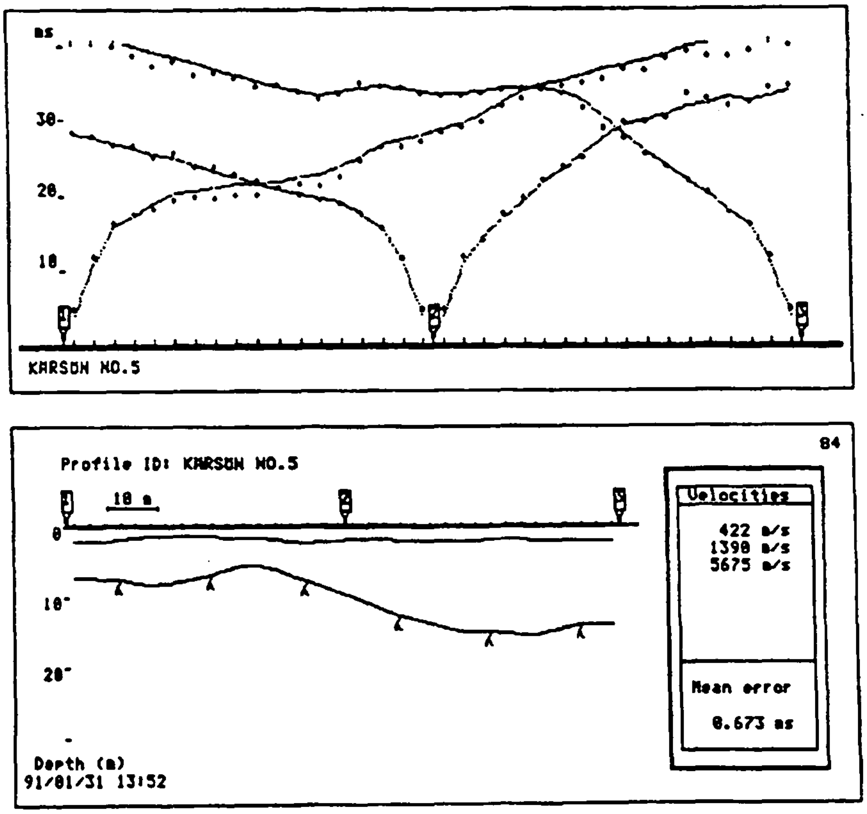
The last step in the interpretation is to find the best model that corresponds to the measured data. For this purpose a ray-tracing optimization algorithm is build into the MINILOC. To run this program, go to the interpretation menu again and select *OPTIMIZE*.



The model is then displayed graphically on the screen. The velocities (taken from the *START MODEL* menu above) are displayed to the right. Each layer interface is divided into 35 line segments (corresponding to the shot point separation), and these line segments are automatically adjusted up and down. The optimization is performed iteratively in a least-squares sense. the algorithm adjusts first interface 1, then 2 etc., and repeats this procedure a number of times. The total number of iterations is default set to 3, but can be changed in the *PARAMETERS* menu.The "Mean error" displayed is the total deviation (in milliseconds) between the measured data and the model response, divided by the total number of data points (which is 3x36 = 108).



At any time during the iterations process you can interrupt the program. For example, you might want to look at the model response and the fitting. For that purpose, choose *DISPLAY* and *RESPONSE* in the interpretation menu (80), and the upper diagram in the following display will appear.



Data fitting (upper diagram) and corresponding model (lower diagram). The mean error is defined as the total deviation between the measured data and the response, divided by the number of data points (108). A value less than 1msec means that the fitting is very good.

In this plot the measured data is indicated by symbols, and the model response by continuous curves. The corresponding model (lower diagram) is presented by selecting *DISPLAY* and *MODEL*.

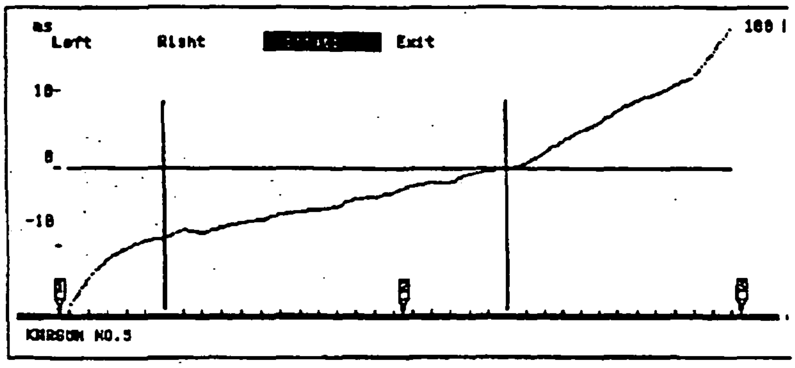
The above procedure assumes that the velocity is constant within each layer. However, it is possible to have varying velocity in the bottom layer. The velocities are calculated by the Mean Minus T method (MMT), and is activated from the interpretation menu also.

MMT calculation

To MMT method provides a way to find the velocity in the lower refractor, please refer to chapter 5 for a more detailed expression. When you activate the *MMT-CURVE* menu 100 appears on the display.

On this curve it is necessary to identify the part of the curve that corresponds to the lower refractor. This is the central straight part of the curve (where the slope is smallest) , which corresponds to the highest velocity.

To set the borders of the bottom refractor curve, move the left and right marker (vertical thin line) to the appropriate position on the curve. The markers are moved with the + and - keys. You have to set both the left

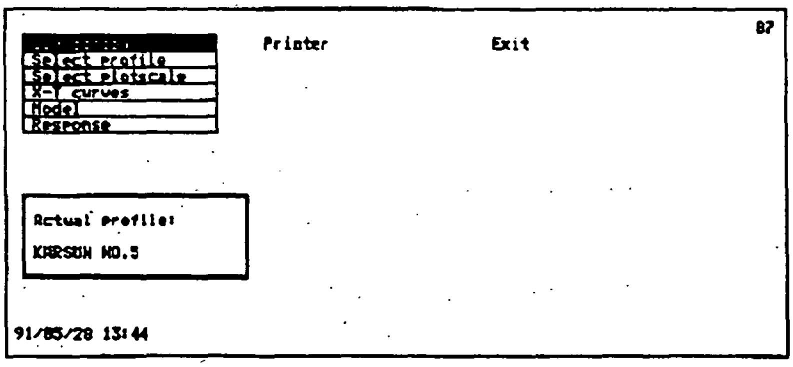


as the right border. When finished select *COMPUTE*. This implies the optimization program to use the velocities from the MMT calculation instead of a constant velocity. A low-velocity zone in the lower refractor is indicated on the model display by a hatched line.

The result of the MMT calculation does not appear directly on the MINILOC. The detailed velocity in the bottom refractor can however be listed in the printout.

3.4.4 Printout

The MINILOC supports printers compatible with the IBM Graphics or



EPSON standard. The printer is connected with a standard printer cable (parallel) to the printer port on the back panel.

At any time you can make a hard-copy of the MINILOC display, simply by pressing the COPY key. This will create a screen-dump on the printer.

Detailed printout of the data and results can be achieved from the *PRINT REPORT* menu (select *PROFILE* in the main menu). In this menu you can choose between transferring the selected information to the LCD display or to the printer. On the printer you will get additional printout of numerical data, e.g. first arrivals and refractor velocity.

4 Seismic measurement theory

In this chapter we will give a more general description of the seismic measurement theory, primarily to supply background information of theoretical character. For further information about the theoretical aspects, please consult some of the relevant text books in this topic.[2]

4.1 Introduction

The seismic methods of geophysical prospecting uses the fact that elastic waves travels with different velocity in different medias.

The principle of seismic investigations is to initiate an elastic wave (shock wave) at a point and determine at a number of other points the arrival time of the energy that has travelled in the different rock formations. By geometrical calculations it is possible to interpret the seismic velocity and thickness of the different layers.

In seismic prospecting we are in principle using two different methods.

- The refraction method
- The reflection method

In the refraction method the main interest is the arrival time of the first part of the seismic pulse, the refracted wave. In the reflection method the later arrivals, the reflected waves, are also used.

Both methods make it possible, if properly handled, to interpret data in an almost unique and unambiguous way.

4.2 Seismic waves and their propagation

4.2.1 Seismic waves

If an elastic medium in equilibrium is exposed to a sudden shock wave, for example a hammer impact, the stress in the medium will propagate as an elastic wave.

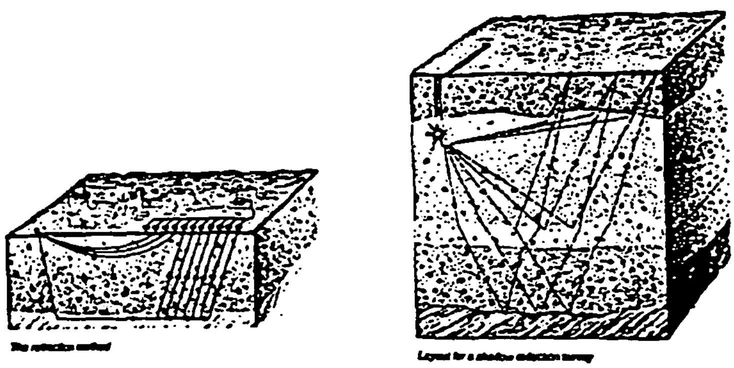


Fig 4-1. The refraction and reflection methods in seismics.

2 A relevant title is "Shallow Refraction Seismics" by Bengt Sjogren.

There are two types of elastic waves - bodywaves - that can travel inside a medium.

- Longitudinal or P waves
- Transverse of S waves

A third type of wave is called Rayleigh-wave, after the finder. This type of wave differs from P- and S-waves since it is a surface wave, i.e. it will in principle travel only on the surface of a medium. The amplitude of the surface wave is decreasing exponentially with the distance from the surface.

Each of the above mentioned wavetypes cause a slight momentary displacement of earth material as it passes through (fig 4-2). The P-waves cause a back-and-forth (compressional) motion which is parallel to the direction in which the wave is travelling. S-waves cause a sideward (shear) motion which is perpendicular to the direction in which the wave is travelling. Rayleigh surface waves cause an elliptic kind of motion, part of which is parallel to the surface of the earth along which the wave is travelling and part of which is perpendicular to the surface. The surface wave thus includes both a horizontal and a vertical displacement component.

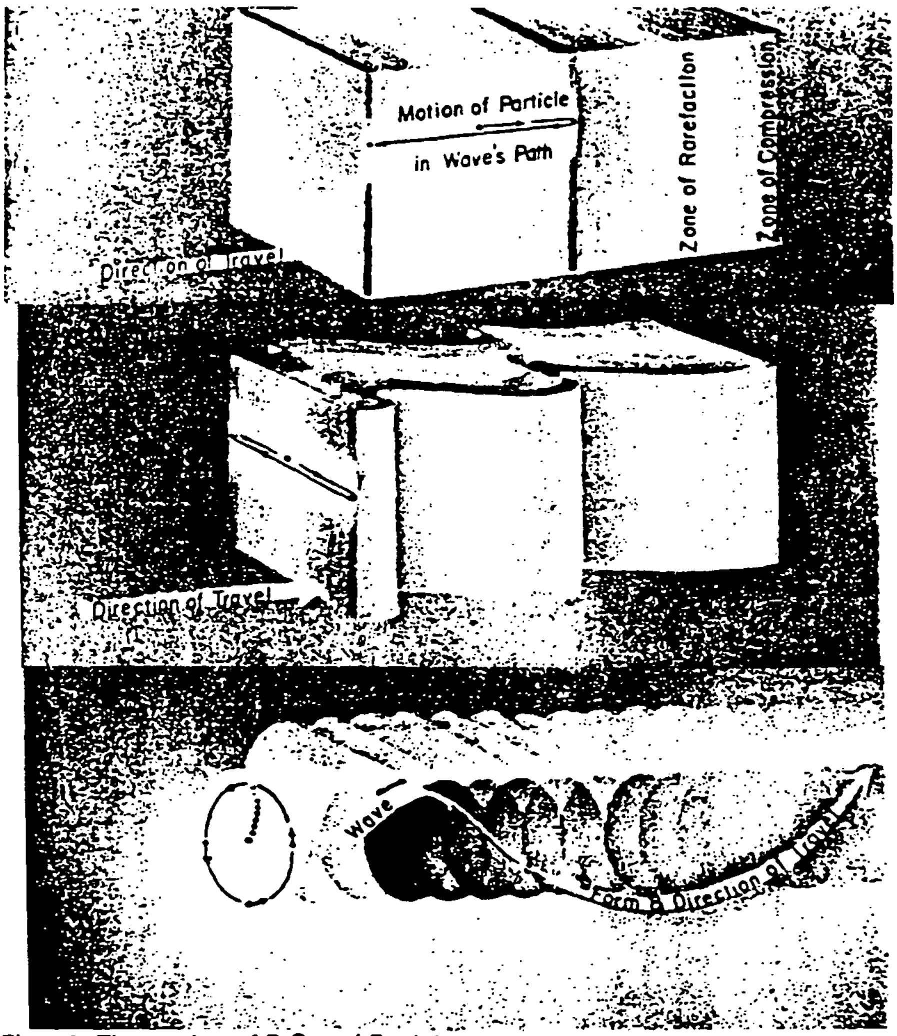


Fig 4-2. The motion of P, S and Rayleigh waves.

Fig 4-2 illustrates the motions associated with each of these wave types for a wave travelling horizontally.

4.3 Seismic wave velocities

The seismic wave velocity in a medium depends of the density (ρ) and the elastic properties of the medium. The relationship can simply be written as:

$$V = (\text{elasticity}/\text{density})^{1/2}$$

Looking at the P- and S-waves specifically the relations are:

$$V_p = (k + 4n/3)/r)^{1/2}$$

and

$$V_s = (n/\rho)^{1/2}$$

where k is the Bulk Modulus and n is the Shear Modulus (both measured in Newton/meter^2).

As a simple rule of thumb we usually say that the S-wave velocity is 60% of the P-wave velocity. For poorly consolidated rock types a value 45% is probably better. The Rayleigh-wave velocity is approximately 90% of the S-wave velocity.

The observed surface wave velocities are, however, somewhat lower than given in the equation above. This is because the Rayleigh wave travels along the surface where lower velocities are normally encountered and the surface waves tend to disperse (the wave velocity depends on the wave frequency). The low-frequency parts are followed by higher and higher frequency waves.

The frequency of body-waves (P-S waves) is normally between 15-200Hz. The surface waves are usually of a frequency lower than 15Hz.

The wave length λ of the different wavetypes follows from the relationship between the velocity v and the frequency f:

$$\lambda = v/f$$

There are several methods to find the seismic velocity of a medium. In the laboratory the best way is to use a so called sonic to measure rock samples. In the field the velocity can be determined from ordinary registrations of arrival times and distances. In the table below you find some typical velocities found in practical studies.

Seismic velocities of selected materials

Material	Vp [m/sec]	Vs [m/sec]
Air	330	Nonexisting
Sand	300-800	100-500
Water	1450	Nonexisting
Moraine	1500-2700	900-2600
Limestone	3500-6500	1800-3800
Rocksalt	4000-5500	2000-3200
Granite	4600-6500	2500-4000
Diabase	5500-7000	3000-4500

From the table you can see that the velocity seems to increase with increasing density quite contrary to what was discussed in the beginning of this section. The reason for this is that the elastic properties (k and n) of the materials will increase faster than the density. This makes the ratio elasticity/density increasing when the density increases.

4.4 Refraction and reflection of elastic waves

As other types of waves like light waves, seismic waves will be refracted and reflected at the boundary between media with different physical properties.

In Fig. 4-3 is shown how an incoming wave will be refracted and reflected at the boundary between medium 1 and medium 2.

When a seismic wave meets the boundary new waves will arise. These secondary waves will, as the primary wave, follow the law of Snell;

$$\sin(I)/V_{1p} = \sin(\theta_p)/V_{1p} = \sin(\theta_s)/V_{1s} = \sin(\varphi_p)/V_{2p} = \sin(\varphi_s)/V_{2s}$$

Where V_{1p}, V_{2p} and V_{1s}, V_{2s} are the P- and S-wave velocities and I, θ_p, φ_p, θ_s, φ_s, are the angle of approach for the primary wave, reflection- and refraction angle respectively for the arisen P-wave and reflection- and refraction angle respectively for the arisen S-wave.

The relations above are valid both if the primary wave is a P-wave or an S-wave. In seismic exploration we are mostly using P-waves since it is hard to create S-waves with enough energy to be used in prospecting work.

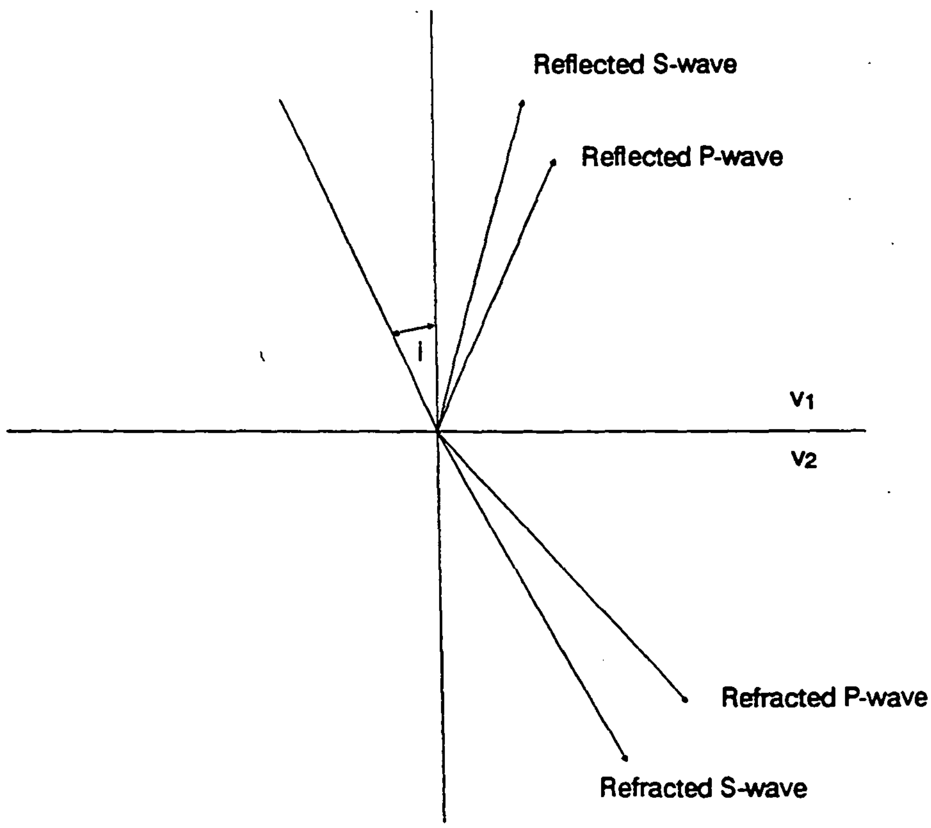


Fig 4-3. Reflection and refraction at a seismic boundary.

S-wave analysis is mostly used in studies of material conditions. By registration of both P- and S-wave velocities the E-modules and k-modules etc. can be calculated.

4.4.1 Volume waves in stratified medias

By studying volume waves (P- and S-waves) that are reflected at and refracted along seismic boundaries close to the earth surface we get important information about the composition of the different geological layers.

We will start discussing the expression "wave front" and "wave path". Suppose that an energy source (explosion or hammer/shock plate) is acting at a point on the surface. In a homogenous and isotropic medium the energy will spread in the equally in all directions.

The wave-front will then look like an expanding half-sphere around the explosion point. By regularly "freezing" the position of the wave front an image showing the propagation of the seismic energy can be constructed like Fig 4-4. In this figure the position of the wave-front each 10 ms is shown. The wavepath is the curve that perpendicularly cuts every wave-front.

Another type of wavefront should be mentioned - the diffracted wave-front - that is generated when a wavefront meets a boundary. This type of waveform is built up of a nearly plane parallel system (see fig. 4-4). The origin of this waveform is based on the principles of Huygen that states that each point on a wavefront acts as a source for an expanding spherical wavelet and that after a time lapse the envelope of all these wavelets defines the new wave-front. The raypaths are perpendicular to the wave-front in an isotropic medium (see fig. 4-4).

We are now going to look at a two-layer case i.e. a layer with a lower seismic velocity resting on an infinite substratum with a higher seismic

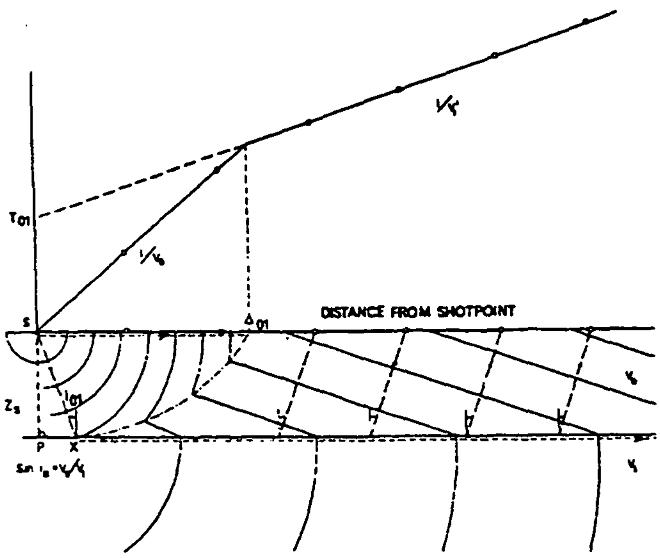


Fig 4-4. Spherical and diffracted wave fronts with ray paths.

velocity. In this case we can differ between the following wavetypes (fig. 4-5):

a) The direct wave that propagates from the source to the observation points without being reflected, diffracted or refracted (wavepath 1). The travel time for this wave is found simply by this equation.

$$t_d = x/v_o$$

where

t_d = the travel time of the direct wave
x = surface distance between the source and the observation point
v_o = P- or S-wave velocity

b) The reflected wave. This wave type is reflected at the seismic interface at depth z from the surface. We distinguish between the following possibilities:

Close to the source the angle of incidence is less than the angle of total reflection. This means that one part of the total wave energy will continue downwards (diffracted wavepath 3), while the other part will be reflected back to the surface.

The amount of the reflected wave energy and its phase related to the incoming wave depends on the contrast between the physical parameters i.e. the acoustic impedance of the different media. The amplitude ratio between the reflected and incoming energy:

$$A_r/A_i = (v_1\rho_1 - v_2\rho_2)/(v_1\rho_1 + v_2\rho_2)$$

where ρ is density and v velocity.

The travel time for the reflected wave is:

$$t_r = 2(x^2/4 + z^2)^{1/2} / v_0$$

where z is the depth to the seismic interface and v_0 the seismic velocity of the upper layer.

If the angle of incidence is greater than the angle of total reflection then all of the wave energy will be reflected (wavepath 6 in fig. 4-5).

- Of special interest is the wavepath that meets the boundary at point B in fig. 4-5 (critical angle i_c for total reflection). Here a diffracted wave will be generated that travels along the interface surface.

The wave type that will travel along the surface of the second layer is called the Mintrop-wave or Head-wave. Mintrop was a German geophysicist first to observe this wave type. In refraction seismic the Head-wave is the only wave type we need to consider to be able to calculate depths and velocities.

Looking at the case when a seismic wave meets the boundary at an angle of incidence equal to the critical angle we get according to Snell's law;

$$\sin i_1/\sin i_2 = v_o / v_1$$

$$i_2 = 90^\circ,\ \sin i_2 = 1,\ i_1 = i_c$$

which gives

$\sin i_c = v_0/v_1$, or $i_c = \text{Arcsin}(v_0/v_1)$

The distance for which this condition will be fulfilled for the first time in the time-distance graph is called the cross-over distance.

The travel time for the raypath H - B - C - D is;

$t_n = \overline{HB}/v_0 + \overline{BC}/v_1 + \overline{CD}/v_0$

or,

$t_n = x/v_1 + (2z-h_0)/(v_0 \cos i_c) - (2z-h_0) \tan i_c/v_1$

using

$\tan i_c = \sin i_c/\cos i_c, \; v_1 = v_0/\sin i_c$

we get further:

$t_n = x/v_1 + (1 - \sin^2 i_c)(2z-h_0)/(v_0 \cos i_c)$

or,

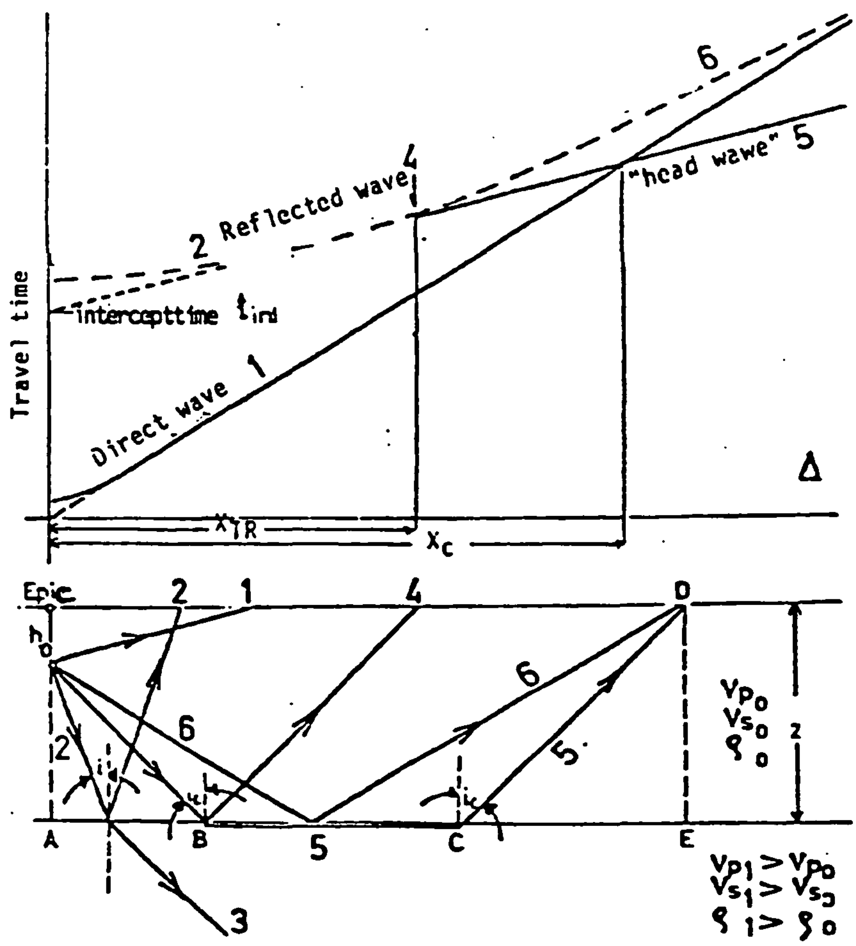


Fig 4-5. Seismic wave paths and traveltimes in a two-layer case.

$t_n = x/v_1 + (2z-h_o)(1 - (v_o/v_1)^2)^{1/2} / v_o$

If the source is at the surface $h_o = 0$ we get

$t_n = x/v_1 + 2z\,(1 - (v_o/v_1)^2)^{1/2} / v_o$

This result shows that the arrival times (t_n) plotted against distance will form a straight line with a slope equal to $1/v_1$. The line will cross the t-axis at

$t_{int} = 2z\,(v_1{}^2 - v_o{}^2)^{1/2} / (v_o v_1) = 2z\,(v_o{}^{-2} - v_1{}^{-2})^{1/2}$

This time is called the intercept time.

The depth z is given by this equation:

$z = t_{int}\, v_o\, v_1 / (2\,(v_1{}^2 - v_o{}^2)^{1/2})$

The velocities v_o and v_1 are found from the reciprocal slope of the travel time curves. Using t_{int} the depth z can be calculated.

Another method to calculate the depth z is to use the distance x_c i.e. the distance from the shotpoint to the cross-over between the travel time curves of the direct wave and the head wave. This distance is called the crossover distance x_c.

Using the $t_d = t_n$ we get

$z = x_c/2\,((v_1 - v_o) / (v_1 + v_o))^{1/2}$

The same concept can be used for reflected impulses. A travel time diagram is constructed in the same way as before but using a quadratic scale in both the time- and distance axis. For calculation of the depth z it is only the mean velocity v_m that is of interest even if the velocity distribution is very complicated.

Looking at two reflections at the same boundary but registered at different distances, using the notations given in fig. 5-6 we will get:

Reflection 1: $(v_m t_1 / 2)^2 = (x_1 / 2)^2 + z^2$

Reflection 2: $(v_m t_2 / 2)^2 = (x_2 / 2)^2 + z^2$

$$v_m{}^2 = (x_1{}^2 - x_2{}^2) / (t_1{}^2 - t_2{}^2)$$

From the reciprocal slope of the time distance curve we get the square of the mean velocity. The depth z can be calculated using the intercept time.

By setting x_1 or x_2 equal to 0 the equations above can be written

$z = v_m t_{1\,int} / 2$

$z = v_m t_{2\,int} / 2$

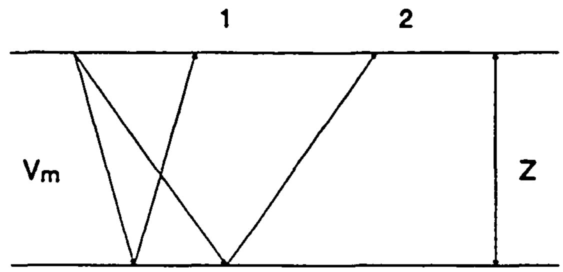


Fig 4-6.Reflection at horizontal boundary.

4.5 Refraction Seismics

Since seismic investigations yield a great variety of reliable data such as depth of various overburden layers, depth-to-bedrock, soil composition and solidity, rock quality, rippability, excavatability, water tables and rock structure, the results are utilized for a wide range of applications, some of which are listed below:

Underground:

- Tunnels and their entrances, machinery halls, gas and oil storage facilities, air raid shelters.

Excavation

- Harbor basins and entrances, pipelines, canals, roads, railways.

Foundations

- Heavy industrial buildings, bridges, harbor quays and breakwaters, dams, piling, airfields.

Resource searches

- Gravel, sand and quarry sites.

Water prospecting

- Groundwater table in the overburden, water-bearing sections of rock.

Ore prospecting

- Mineralized weathered zones, buried channels with high mineral content.

A seismic survey is of unique value because it provides:

- Good economy. An immense amount of useful data is obtained at a very reasonable cost.
- A continuous picture of the underground geological conditions. This substantially reduces the risk of overlooking critical or promising areas.
- Terrain-independence. Rough terrain, urban sites and water-covered areas can all be surveyed with equal ease.

The following parameters are measured and computed. They are used for both interpretation and evaluation:

Apparent / average longitudinal velocity, v_p

- Apparent velocities - after being corrected - are used to determine thicknesses of layers, interfaces between discrete layers, water table and total depth-to-bedrock.

Apparent / average transverse velocity, V_s

- Apparent / average transverse velocities are used - in conjunction with longitudinal velocities - to evaluate material composition and rock quality. Unlike longitudinal waves, the transverse waves are not affected by the water content of a material.
  To evaluate the dynamic properties of soil and rock layers, the following parameters can be computed using longitudinal and transverse velocities and the material density.

To provide a more comprehensive picture of the composition and consolidation of a material, an interpretation can include analyses of amplitudes and frequencies.

The extensive use of the seismic refraction method for civil engineering in Sweden and later in many other countries under a wide range of climatic and topographic conditions including use across rivers and lakes has accelerated development and improvement of the necessary equipment.

The type of field work to be carried out with seismic refraction equipment plays an important part in instrument design philosophy. A brief description of the present practice of refraction profiling and its applications is therefore warranted.

4.5.1 Refractor Velocity Determination - MMT

Ideal geological conditions are seldom encountered in nature. The travel time curves are generally affected by variations in ground elevation, layer thickness and velocity. Particularly the upper, dry and loose layers often heavily distort the recorded arrival times, sometimes to such a degree that reliable and accurate interpretations are impossible.

A stable and safe way to estimate the bottom refractor velocity is the Mean-Minus-T (MMT) method. In Fig. 4-7, the time differences T between the direct and the reversed recordings are computed for each shot-point and divided by two. The resulting times are then plotted at the associated shot point positions relative to a horizontal reference line. This method involves systematic averaging of time increments between adjacent shot points. When the adjusted travel times are connected (dashed line), an acceptable evaluation of the refractor velocity distribution is possible. In this example there is a considerably lower velocity in the central part of the traverse, thus indicating the presence of a shear zone.

A detailed determination of refractor (bedrock) velocities considerably increases the usefulness of the refraction method since the lower velocities indicate weaker rock sections such as faults, jointed or weathered zones. These zones are often strongly waterbearing.

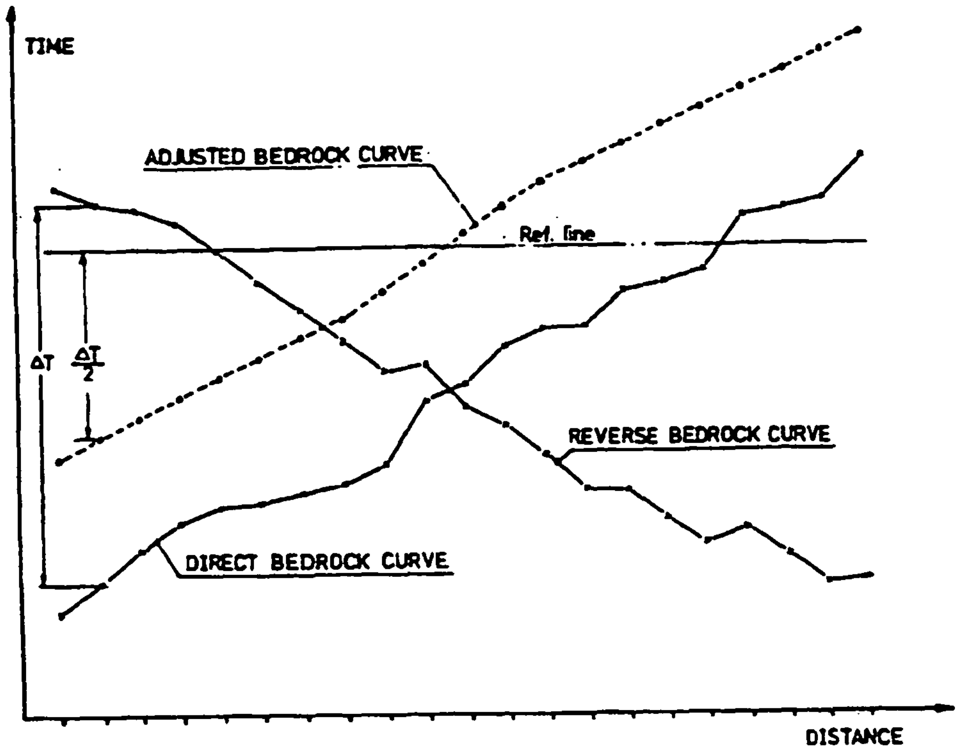


Fig 4-7. Average refractor velocity determination. The adjusted bedrock curve is the result of the MMT calculation.

Before commencing the calculation of average refractor velocities, make sure that the arrival times to be used refer to the same refractor. Otherwise, serious errors will be introduced.

The MMT curve can be calculated and displayed directly on the MINILOC.

4.5.2 Limitations and pitfalls

As stated in the introduction to this section, the basic formulae make certain assumptions. When actual conditions do not fulfil these assumptions, then seismic refraction results may be disappointing or even incorrect. These pitfalls must be taken into account and all results should be evaluated with them in mind.

4.5.3 Incompetent overburden material

When the upper overburden layer is of loose, unconsolidated material, the seismic velocity in such a layer may be low, sometimes even lower than that of sound waves in air. If velocities of first arrivals have values near the velocity of sound waves in air, they should be treated with caution.

If the loose material is water saturated, higher velocities of the order of 1500 m/s may be encountered. This may give the impression of a relatively compact earth layer, but it should be remembered that about 1500 m/s is the compressional Wave velocity in water.

4.5.4 No velocity contrast

It is not always certain that layers with different mechanical properties will show distinct velocity contrasts. Seismic velocities do not necessarily conform to geological strata, and correlation with drilling results should be carried out whenever possible.

4.5.5 Hidden Layers

A hidden layer is used to describe the conditions in a three layer case where the intermediate layer is thin and has a velocity V_2 much lower than that of the underlying layer V_3, Fig. 4-8. In such circumstances the wave refracted into the third layer travels at high velocity and may overtake the first arrivals from the second layer. Second arrivals, if not masked by "grass" attributable to first arrivals on the seismogram, may indicate by their line-up the presence of the hidden layer.

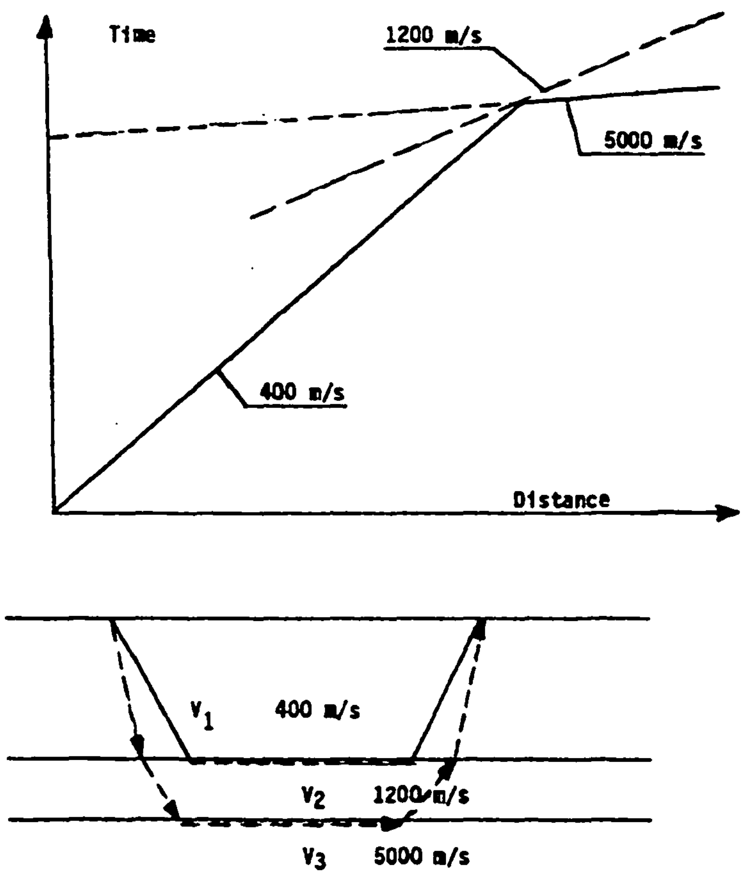


Fig 4-8.The hidden layer problem.

The thin hidden layer does not show up easily or clearly on the seismogram. If it is ignored, serious errors will be caused in depth calculations to the third layer. Presence of a hidden layer may be suspected (a) if a second layer identified elsewhere along the profile thins out and finally disappears from the seismogram, (b) if drilling definitely shows the existence of a second layer of (c) if correlation of seismic results with geological or other geophysical data indicates that the first layer is thinner than the seismic interpretation.

The hidden layer problem can successfully been solved by the combination of refraction and shallow reflection surveys.

4.5.6 Reversed velocity relation, Blind zone

If the increase in velocity with depth is inverse and a lower layer has a velocity less than that of the layer above it, then such a layer is undetectable by refraction methods. A blind zone refracts the entering wave towards the vertical and rays entering the zone never return from its upper surface. Presence of a blind zone will cause the calculated thickness of the layer above to be too great, and will give too great a depth to the layer underneath.

4.6 Shallow Reflection Methods

In recent years methods for the conduction of reflection seismic surveys have been developed for shallow depths (15-500 m) using engineering seismographs of the enhancement type. Two such methods are described below. These are the CDP (Common Depth Point) and the Common Offset (also called Optimum Offset) methods. The methods differ mainly in the amount of data that is recorded and processed and therefore also in the requirement of processing computers and programs. The field data augured for a CDP survey will as a subset contain the Common Offset data thus enabling alternative processing at a later stage.

The MINILOC is well suited for the Common Offset method.

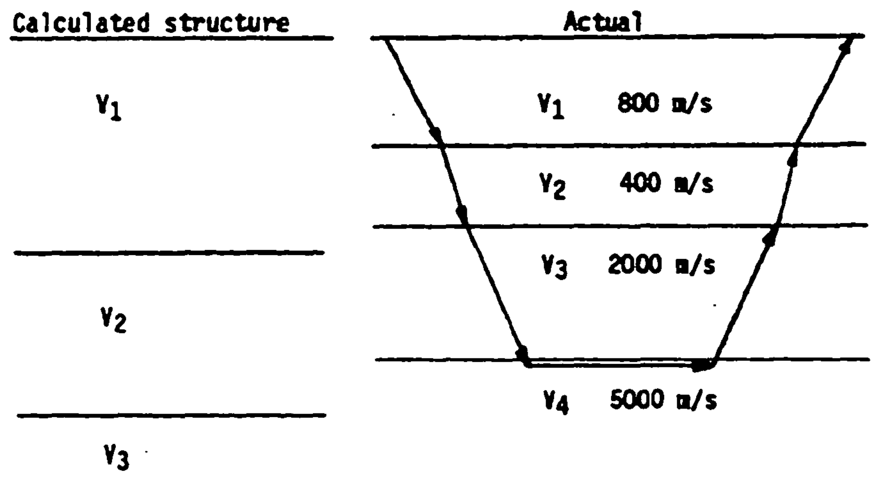


Fig 4-9.Reversed velocity relation, blind zone.

All reflection seismic methods produce so called time sections from the data collected in the field at an intermediate stage in the processing. The time section consists of a large number of received signal traces related to successive geographical locations all displayed side by side on a plot diagram.

By visual correlation of signal pulses that occur at nearly the same time from trace to trace one can see a subsurface structure of reflecting boundaries. To make this easier the section is normally plotted using the variable area trace type.

The processing necessary to go from a time section to a depth section depends on the complications of the geological structures visible in the time section. If the section is very simple in structure the only necessary step may be the relabelling of the time axis into a nonlinear depth scale. However, in most cases (Especially the interesting ones!) this is not immediately possible. First one must "migrate" the section. By migration is meant the process whereby the reflections and diffractions visible in the section are moved to the correct positions in the same section. Due to the ray bending and slant reflections in curved or dipping structures and the diffractions caused by faults the signal received at one place may have originated at another place. It is the objective of the migration program to compute from where the signal came and move it there. Migration programs are somewhat complicated and can be obtained from several sources, for example universities and processing companies.

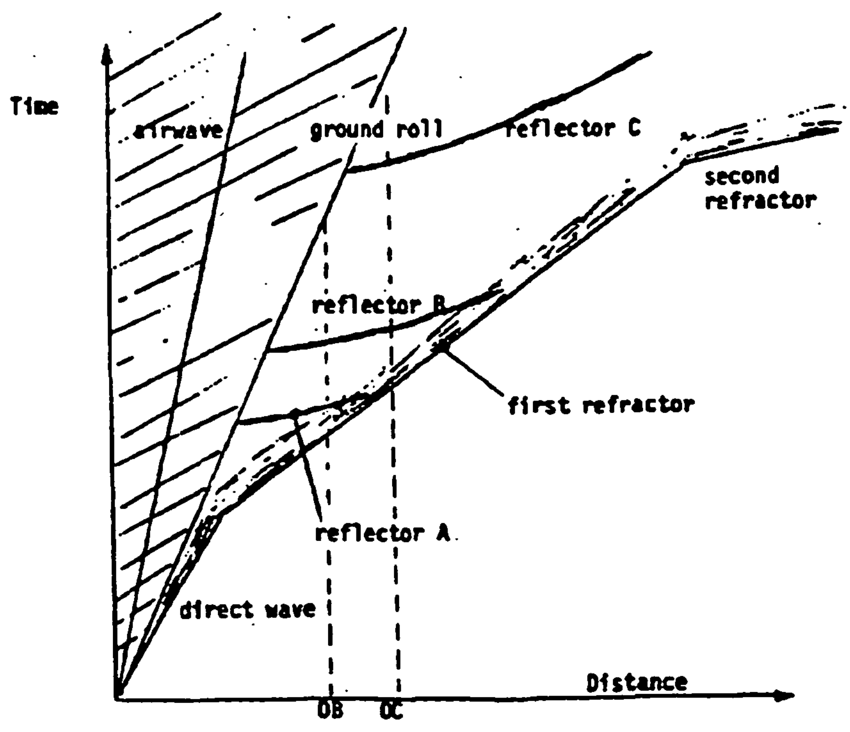


Fig 4-10. Time-distance graph showing the positions of important events. The "window" between OB and OC is suitable for Common Offset measurements.

4.6.1 Signal sources for reflection work

Seismic sources to be used with this method shall produce a fairly short signal signature (have good high frequency content) and also have en energy output that is in accordance with the target structure depth. There is an assortment of different sources on the market and they all have their special use, none being universally adaptable to every case.

For shallow work down to 20-30m depth the source must have a very definite high frequency output and a short signature. Low energy content is important. Examples are ignition caps and small caliber blank shells fired below the surface. A sledge hammer on a steel plate will in many cases generate a suitable signal.

4.6.2 Geophones for reflection work

Since the object is to detect the structure in detail you will need to collect high frequency data so the use of high frequency geophones with a natural frequency of about 100 Hz is recommended. Note that the useful frequency range of any geophone is limited by internal resonances to about 10-15 times the natural frequency. Above this frequency the received signals will be distorted by the resonances Thus, to record signals to 200 Hz you need a 20 Hz geophone and for 500 Hz a 50 Hz geophone. These phones will also reduce the low frequency ground roll interference.

In the absence of such phones an amplifier filter function of the low frequency ground roll without saturating any preamplifiers before the filter. The frequency of the low-cut filters may be set at 35Hz to 280Hz (in steps of 35Hz) depending on conditions.

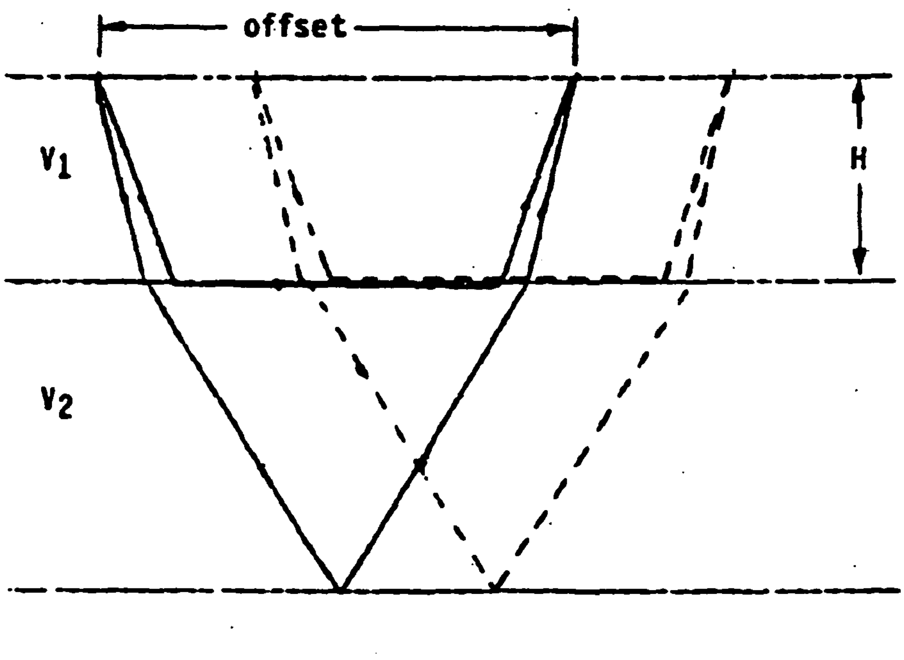


Fig 4-11. Raypaths for two common offset shots showing reflected and refracted waves.

4.6.3 Common Offset Measurement

This technique has the advantage that it does not need external data processing to produce the final reflection section. The functions available in the Miniloc are sufficient to collect the data, remove the static variations, equalize the signal levels and make a hardcopy printout.

On the other hand the data quality will depend strongly on careful measurements in the field including selection of recording parameters and monitoring of data quality. This is due to the fact that no stacking of traces is done and consequently there will be no improvement in data quality from averaging. Therefore one must make sure from the outset that the reflections are visible and situated between the refracted wavelet and the ground roll noise. See Fig. 4-10.

If the target structure is reflector B then an offset OB may be selected. This offset will unfortunately submerge reflector C in the ground roll but is just about right to detect reflector A as well. When C is needed an offset OC must be selected that moves C out from the ground roll noise. As a side effect of this reflector A disappears completely into the refracted first arrival.

In short, using the common offset method one must select the shot offset carefully based on the target depth, refraction velocities and ground roll velocity and amplitude. It will not be possible to find a suitable compromise in all situations but when it can be done the survey will be quite straightforward and results can quickly be produced.

This method is particularly suited to shallow work in areas with high water table level.

4.6.4 Layout for the Common Offset Method

The basic geometry of the common offset method can be seen in Fig. 4-11 showing two shots. As can be seen the reflection point moves ahead by the same distance as the shewed does. Another observation is that the refracted and reflected rays travel through the top low velocity layer close to each other. This gives an opportunity to use refracted arrivals to compensate for weathering layer variations (static correction). To do this the whole trace is time shifted so that the first arrival is moved to a time equal to the offset divided by the velocity of the lower layer (V_2). This can be done entirely within the MINILOC itself.

Because the MINILOC is a three-channel seismograph, three offsets are conveniently measured simultaneously.

The result is a record that looks like what would have been measured if the shot and the geophone had been placed on a datum plane at a small distance above the V_1-V_2 interface. This distance is equal to $H*(V_1/V_2)^2$ which means that a considerable reduction of topological variation is obtained whenever V_1/V_2 is small. As an example consider the case where V_1 is 500 m/s and V_2 is 1600 m/s. This results in a ten times reduction of layer variations in the final section.

4.6.5 Field procedure for Common Offset Measurements

For data collection according to this method three geophones will actually record data for each shot. Before starting the profile, make a few test shots with different offset. Based on these shots the offset to be used is determined so that the target reflector will fall within the reasonably quiet window after the refracted wave but before the ground roll arrives.

A complete MINILOC profile consists of 36 shot points. If three geophones with different offset has been used, three different sections (focussing on different target reflectors) can be presented.

For a longer profile the data is transferred to a PC computer and/or printed out, and the memory is cleared. The process is then repeated at the next profile until the profile has been covered. The same shot-geophone offset distance must be used throughout.

4.6.6 Data processing for Common Offset Surveys

The records made are composites containing typically 36 traces with data from 36 different shots. Since they have been recorded with the same offset for each trace the records have the appearance of a reflection section. The processing that can be applied is removal of static variations due to the weathered overburden. This is quite simply done by identifying the refracted first arrivals and using this refractor as a datum plane to correct all traces to an equal time for this event. In doing this the variations caused by the layers above the refractor are reduced. Instead any level variations in the refractor itself will be transferred to the reflector horizons below so this effect has to be taken into account during interpretation. In most cases the refractor is the groundwater table and can be assumed to stay fairly uniform.

Practical data processing on the Miniloc:

With the data collected in the form of 36 channel common offset records all processing needed to produce a printed section can be done within the Miniloc.

These processing steps include:

- Static correction
- Amplitude equalization
- Hard copy printing

They are performed as follows:

STATIC CORRECTION

Engage the automatic arrival picking routine to pick the refracted first arrivals. Then choose *EDIT* from the *INTERPRET* and *FIRST BREAK* menu to adjust the time marks where necessary. Note how the use of trace types (variable area or curve) as well as different settings of the Normalizing window will help in accurately picking these arrivals.

From a separate record the refractor velocity should have been found. Using this and the offset distance the correct value for the time shift parameter can be found as:

$$t = 1000\,\Delta x/(T\,V_r)$$

where t is the time shift (in msec), Δx the offset distance (in meters), V_r the refractor velocity (in m/sec) and T the total record length (in msec).

Note, that the parameters in the above relation are specified in the MINILOC menus. The offset distance is specified in the *REFLECTION* menu, the record time in the *SETTINGS* menu and the refractor velocity in the *SHOW DATA* menu.

AMPLITUDE EQUALIZATION

Set the window (in the *SHOW DATA* menu)so that the window will include the data up to the arrival of the air wave or the ground roll noise. If the recording was made with a 200 ms record length and the offset was 35 m then the air wave will arrive at 100 ms. The refracted wave may have arrived at 25 ms which will give a usable span for equalization of 75 ms.. In this case the window is therefore set to 75 ms.

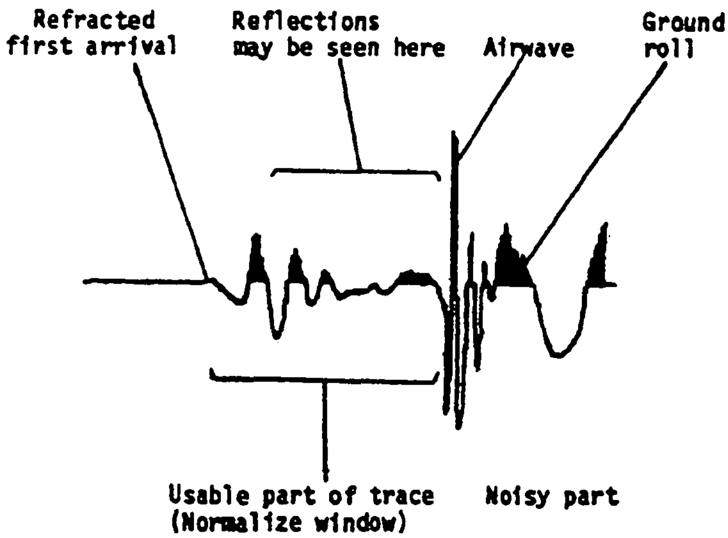


Fig 4-12. The different events within the trace.

5 Service and maintenance of the MINILOC

The MINILOC system is designed to withstand the normal wear and tear encountered in field work.

5.1 General precautions

- Excessive vibration, temperature and moisture exposure should be avoided.
- Do not transport the instrument loose on vehicle floors or truck beds.
- Avoid excessive temperature exposure such as direct sunshine in hot weather.
- Do not expose the instrument to rain for long periods. It is splash proof but not submersion proof.

5.2 Storage and humidity

When not in use, instruments should be stored in dry premises.

If the instrument is exposed to excessive humidity during a long period, it can be dried by lifting the circuitry out of the case and letting it dry in the sun or near a stove. Remember, however, that **static electricity can damage the circuitry.**

5.3 Service

Opening the MINILOC

Put the instrument upside down and unscrew the four screws using a long screwdriver. The orange box can then be removed directly (take care not to harm the circuit boards when you remove the box). All the four printed circuit boards are then accessible. A part of the computer board is shown in Fig 5-1.

Be careful, static electricity can damage the circuits.

If you need to work with the MINILOC keyboard while the instrument is open, simply turn the instrument upright again.

Lithium Battery

The lithium back-up battery on the computer board has a life time of at least 1 year. Therefore, change this battery at regular intervals in order not to loose data.

In general, the MINILOC will loose all data when the back-up battery is removed. However, if the battery is removed for less than one minute, the condensers will be able to keep the necessary power to the RAM circuits, and no data will be lost. Therefore, before removing the old battery, be sure you have a correct battery for replacement ready. The lithium battery is of type CR 2032 (3.0Volt, 170mAh, dimension 20x3.2mm).

It is recommended to print out (or save on computer) the important data before changing back-up battery.

EPROMS

The MINILOC program is located in four EPROMS on the Computer Board. In case of upgrade of the program you will receive new EPROMS from ABEM. A complete set consist of 4 chips. To release the old PROMS, use a small screwdriver and lift each PROM very carefully right out of the socket, without tilting its legs. Before mounting the new PROMS, be sure that the legs on these are lined up. Place them very carefully and take care that each leg fits exactly in the corresponding hole in the socket.

\>> The orientation of the EPROMS is very important. The small hatch in the EPROM must correspond to the mark on the printed circuit board. The numbering of the proms (U16 to U19) is very important too. Observe, that the last digit in EPROM numbering (16 to 19) corresponds to the last digit in the ABEM EPROM order number.

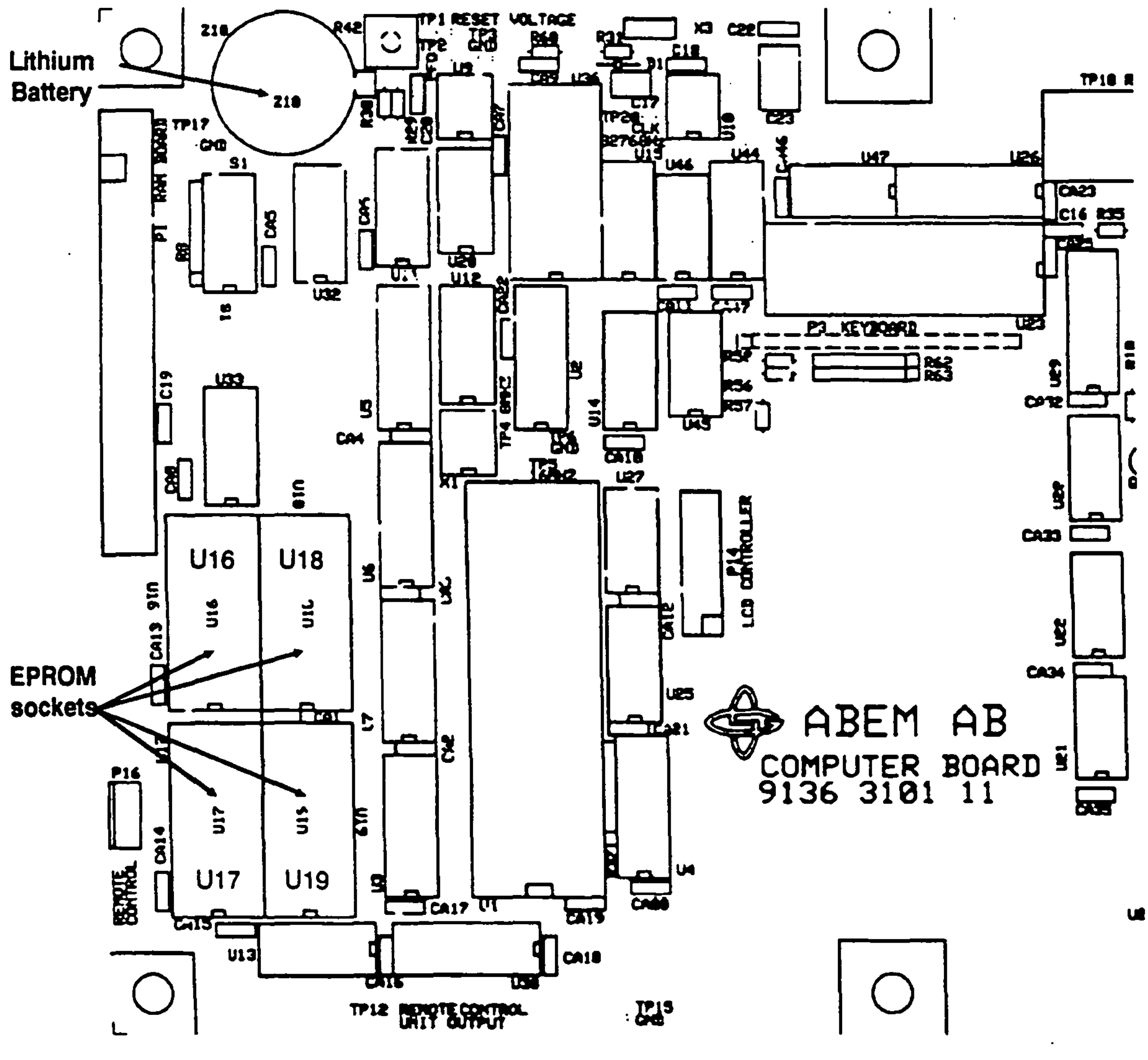


Fig 5-1. The left part of the MINILOC computer board. Observe the polarity of the battery and the orientation of the EPROMS! Do not change the settings of the switches etc.!

5.4 Program System Control

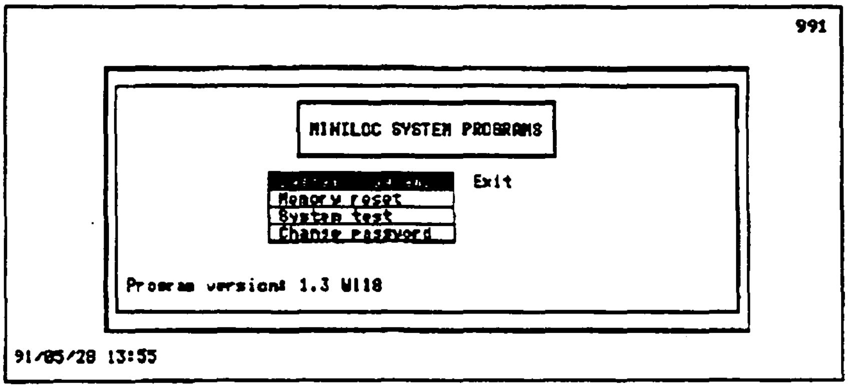
Some basic system control can be performed from the program.

5.4.1 LCD Display Contrast.

The contrast of the Liquid Crystal Display can be adjusted directly from the main menu no 1. Press the + key to make the display darker and the - key to make it lighter.

5.4.2 System Programs

From the main menu (no 1) type SYSTEM (the keys S-Y-S-T-E-M) and the menu (no 991) comes up:



Password

The *CHANGE PASSWORD* option gives the possibility to use a password of up to six characters. By default, no password is used. If active, you will be prompted for a password as soon the instrument is turned on.
Do not forget your password.

Memory Reset

Clears all the MINILOC memory. This function can be used e.g. after change of the EPROMS.

System test

For internal service use by ABEM only.

6 Technical Specifications

6.1 MINILOC instrument

Number of channels:	3
Trigger Input:	Through Remote Control Unit
Sampling Time	0.1, 0.2, 0.4 msec
Number of samples	2048
A/D Converter	16 bit
Frequency range	2 - 1000 Hz
Recording time	200, 400, 800 msec
Notch filters	50 Hz (60 Hz optionally)
Low Cut filters	off, 35, 70, 105, 140, 175, 210, 245, 280 Hz
Input impedance	650 Ohm
Memory	768 kB static RAM for data (3 x 36 x 2048 samples)
Clock	Real time, for documentation
Display	LCD, 640 x 200 pixels
Keyboard	Membrane keys, "QWERTY" layout
Interface	Serial RS232 for PC computer communication CENTRONIX parallel interface for printer
Printer interface	IBM Graphics / EPSON FX80
Power	Internal 12V, 4Ah rechargeable Ni-Cd battery Connection to external 12V battery
Back-up battery	Li/MnO_2, type CR 2032 (3.0V, 170mAh, dimensions 20x3.2mm)
Back-up battery lifetime	1 year (current $< 15\mu$Amp)
Fuse	1.0 A internal fuse
Weight	11.0 kg
Dimensions (LxWxH)	470 x 280 x 320 mm
Temperature	-5° to $+50^{\circ}$ C

6.2 Geophone data

Natural frequency	14.0 Hz $\pm$ 0.7 Hz within 25° tilt from upright
Coil resistance	375 Ohm, 5%
Sensitivity	290 mV/(cm/sec) undamped 180 mV/(cm/sec) with 650 Ohm load, above 20 Hz
Damping	84% with 650 Ohm load
Weight	170g (total), 11g (moving mass) 280g incl cable and connector
Temperature limits	-40° to $+100^{\circ}$ C

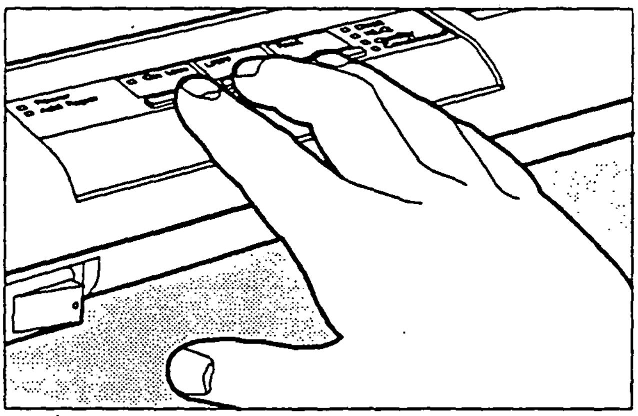
Recharging the Batteries

Your 150 Plus is capable of recharging its own batteries much like a jump start energizes your car's dead battery.

The Power indicator will begin to flash when battery power is low. Generally, you can print two or more pages before all power is gone.

1. Connect the AC adapter and turn the printer on.

2. Press and hold all three operator panel buttons until the Power indicator goes out. (A Font indicator will flash when you release the buttons.)



3. Allow the batteries to charge until the Font indicator stops flashing and the Power indicator comes on. (Recharging can take 10 to 14 hours.)

Hint: Should power be interrupted during the recharging operation, deplete the partially charged batteries and start the recharging process over.

When batteries are fully charged, the printer can operate continuously for a minimum of 50 minutes.

You can send data from the PC to the printer during the recharge operation (high-priority printing, for example). When the 150 Plus receives this data it stops the recharging process and prints (provided it is online and paper is loaded). A short time after the job is finished, the printer automatically resumes the recharging process provided power to the printer has not been interrupted.

APPENDIX 3

TAMWA, SIHAMBE, DHOBANI WELL DATA (Last Update 2/2/94)

WELL OWNER AND TYPE				DATUM DESCRIPTION AND DATA				WELL DIMENSION DATA AND DESCRIPTION					
Well I.D.	Owner	Type	Year Completed	Datum	Elevation (m agl)	Elevation (m argl)	Elevation (m acw)	Depth Sept'93 (m)	Deepened Collapsed (?)	Bedrock depth (m)	Diameter (m)	Lining depth & type	Runoff to well (?)
1	Majazi	Dug well	1987	slab	0.00	0.00	1.92	11.98	no	r 12m	1.05	06.00m stone	no
2	Community	Col.well	1991	wall	0.38	0.38	0.00	12.00	no	r 12m	2.00	15.00m armco steel	no
3	Mhlanga,J.	Dug well	1981	block			-3.16	8.38	yes'91	r 9m	1.30	04.00m stone	no
4	Mhlanga,D.	Dug well	1983	slab			-1.90	9.94	no	> 10m	1.50	10.00m stone	no
5	Siwawa,E.	Dug well	1991	slab			0.97	11.25	yes'91		0.90	10.00m stone	no
6	Siwawa,S.	Dug well	1992	log			3.54	11.75	no	> 11m	0.80	11.00m stone	no
7	Bwerinofa,L.	Dug well	1986	slab			-5.29	11.78		> 15m	0.80	15.00m brick & mortar	no
8	Bwerinofa,L.	Borehole		metal			-5.44	12.00			0.15		no
9	Maphosa	Dug well	1986	slab	0.00	0.00	-2.71	8.90			1.30	03.00m brick and mortar	no
10	Maphosa	Dug well	1964	slab	0.00	0.00	1.53	12.59			1.40	05.00m brick and mortar	yes
11	Mazambani	Dug well	1990	slab			12.75	7.86	no	hr 7.86m	0.80	03.80m stone	no
12	Mazambani	Dug well	1985	slab			10.25	10.32	no	sr 13.69m	1.00	03.20m brick and stone	mended?
13	Muvhimi	Dug well	1989	slab			20.57	13.69	yes'91		1.10	10.00m brick and stone	no
14	Dobani	Dug well		log	0.00	1.27	12.99	6.10	coll '92	r 12.0m	note 1	04.50- 05.50m stone	no
15	Bwerinofa,D.	Borehole	1990	bolt hole	0.13	0.30	11.40	45.00			0.15		no
16	Makiwa	Dug well	1990	slab	0.38	0.38	19.21	11.30		sr 11.30m	0.70	0 - 3m brick 3 - 11m stone	no
17	Dhewah	Dug well	1987	slab	0.43	0.43	12.15	11.30		r 11.30m	1.00	brick all way	no
18	Makiwa	Dug well	1991	log	0.00	0.00	13.47	9.30		> 9.30m	1.60	stone all way	no
19	Dube	Dug well	1961	stone	0.00	0.00	22.54	5.10	coll '93	> 6.30m	2.00	stone all way	no
20	Sithole	Dug well	1990	slab	0.30	0.30	19.47	6.75		> 6.75m	0.75	04.30m stone & concrete	no
21	Riziwe,M	Dug well	1987	slab	0.00	0.00	30.61	7.50			1.40	07.50m stone	no
22	Riziwe,L	Dug well	1992	slab	0.00	0.00	25.22	11.90		> 12m	0.80	stone all way	no
23	Zikali	Dug well	1983	slab	0.00	0.00	15.65	9.12		>9.12m	1.10	04.30m stone	no
24	Mhake	Dug well	1987	log	0.00	0.00	4.98	10.23		r 11.30m	1.56	03.00m stone & logs	no
25	Dobani	Dug well	1987	slab	0.20	0.50	-12.94	12.10		r 12.1	1.50	03.60m concrete	no
26	Bwerinofa,J.	Dug well	1986	log	0.00	0.00	4.63	4.70			1.40	none	no
27	Tarinda	Dug well	1972	log	0.00	0.00	-8.25	7.60		> 7.7m	note 2	03.80m stone	no
28	Sabanda?	Dug well	1975	slab	0.20	0.20	-7.54	10.50		> 10.6m	0.90	02.00m brick & stone	no
29	Tamwa	Dug well	1986	slab	0.20	0.20	-7.48	9.10			1.00	01.75m brick & stone	no
30	Makaza	Dug well	1991	stone	0.00	0.00	-6.30	10.00			0.80	01.50m stone	no
31		Dug well		slab	0.00	0.00	4.27	3.60	coll		1.00	stone all way	no
32	Sithole	Dug well		slab	0.00	0.00	21.84	5.00			note 3	00.80m - 01.10m concrete	yes
33		Dug well		slab	0.00	0.00	24.92	6.05			1.20	none	no
34	Lutheran	Dug well	1992	hand pump	0.40	0.80	-7.80	11.55			1.50	concrete rings	no
35		Dug well		stone	0.00	0.00	26.23	3.60		> 3.6m	1.40	none	no

NOTE
m agl = metres above ground level
m argl = metres above regional ground level (when well is dug on a small mound eg anthill)
m acw = metres above collector well datum

NOTE
r = rock
hr = hard rock
sr = soft rock

NOTE
note 1 :- 2m dia to 4.5m, 1m dia 4.5m to bottom
note 2 :- 3.5m dia to 3.5m, 1.1m dia 3.5m to bottom
note 3 :- 1.4m dia to 3.5m, 0.8m dia 3.5m to bottom

PIEZO No.	DATUM LOC. AND ELEVATION Datum	Elevation (m agl)	Elevation (m acwd)	DRILLING LOGS (1 rod = 0.75m) Date	Total Depth (rods)	Water Strike (rods)	Basement hit (rods)	Time last rod (using DTHH) (mins)	POST DRILLING DIPPING Date	Total Depth (m bd)	Rest wl (m bd)	LOCAL FEATURES Feature, Direction, Distance (See Key Below)
A1	t.o.c		-0.85	01/09/92					17/09/94	13.25	7.98	
A2	t.o.c		-0.85	01/09/92					17/09/94	23.90	7.95	
B1	t.o.c		-1.49	01/09/92					17/09/94	13.50	7.12	
B2	t.o.c		-1.54	01/09/92					17/09/94	63.50	7.05	
C1	t.o.c		-0.61	01/09/92					17/09/94	20.00	8.00	
C2	t.o.c		-0.61	01/09/92					17/09/94	29.30	8.00	
D	t.o.c		-0.72	01/09/92					17/09/94	14.60	7.75	
E	t.o.c		-2.16	01/09/92					17/09/94	13.70	6.87	
F1	t.o.c		0.72	01/09/92					17/09/94	9.50	7.73	
F2	t.o.c		0.73	01/09/92					17/09/94	7.50	block	
G	t.o.c		2.28	01/09/92					17/09/94	10.50	8.09	
H	t.o.c	0.19	-2.18	28/09/93	20.00	14.00	13.00 9.75	10.00	18/10/93	14.74	8.57	GW,a,2
I1	t.o.c	0.08	3.79	29/09/93	11.00	dry	9.00 6.75		18/10/93	8.22	5.63	CB,u,2 / EB,u,80
I2	t.o.c	0.10	7.37	29/09/93	15.00	dry	8.00 6.00		18/10/93	10.43	9.63	A,a,20 / CB,a,18 / EB,a,200
I3	t.o.c	0.20	9.24	30/09/93	27.00	dry	26.00 19.5	9.00	18/10/93	20.25	9.96	CB,u,8
J1	t.o.c	0.13	14.03	30/09/93	6.00	dry	4.50 3.40	10.00	16/10/93	4.63	dry	G,a,2
J2	t.o.c	0.13	14.20	30/09/93	4.00	dry	2.50 1.90	12.00	16/10/93	3.09	dry	CB,d,15
J3	t.o.c	0.14	15.30	30/09/93	8.00	dry	7.00 5.25	12.00	16/10/93	6.05	dry	G,a,2
K1	t.o.c	0.09	17.74	08/10/93	15.00	dry	14.00 10.5	8.00	16/10/93	11.38	dry	CB,d,8 / CB,u,20
K1d	t.o.c	0.18	17.83	25/10/93	32.00	dry	12.00 9.0	4.00	27/10/93	15.00	4.42	As above
K2	t.o.c	0.14	10.79	08/10/93	10.00	dry	9.00 6.75	10.00	16/10/93	7.53	6.50	GW,a,7 / CB,d,25 / CB,u,40
K2d	t.o.c	0.18	10.83	26/10/93	20.00	dry	8.00 6.00	14.00	27/10/93	15.00	12.61	As above
K3	t.o.c	0.13	8.19	06/10/93	16.00	9.00	13.00 9.75	9.00	16/10/93	9.34	3.57	R,d,50 / CB,d,30 / A,u,40
K3d	t.o.c	0.24	8.30	26/10/93	25.00	dry	12.00 9.00	16.00	27/10/93	23.82	11.45	As above
K4	t.o.c	0.15	8.39	01/10/93	11.00	dry	12.00 9.00	11.00	16/10/93	9.51	4.34	CB,u,4 / R,d,50
L1	t.o.c	0.19	1.25	09/10/93	26.00	16.00	25.00 18.75	8.00	14/10/93	8.22	4.74	G,a,95/A,a,50&130/GW,0/CB,u,20/[illegible]
L2	t.o.c	0.15	1.14	11/10/93	15.00	dry	14.00 10.5	6.00	14/10/93	9.90	4.81	G,a,45 / A,u,5 / CB,d,20
L3	t.o.c	0.14	-0.23	15/10/93	7.00	dry	6.00 4.5	7.00	14/10/93	5.33	4.22	G,a,15 / CB,d,5
L4	b.o.g		-1.53	15/10/93	5.00	dry	4.00 3.00	10.00	14/10/93	3.57	3.47	Bottom of gully
L5	t.o.c	0.18	-1.11	15/10/93	5.00	dry	4.00 3.00	10.00	14/10/93	3.74	2.47	G,a,15/CB,u,20/CB,d,50/EB,d,30
L6	t.o.c	0.16	-0.55	15/10/93	13.00	dry	12.00 9.00	10.00	14/10/93	8.30	6.60	G,a,45/CB,d,40/CB,u,23/A,d,35
L7	t.o.c	0.13	-1.13	15/10/93	13.00	dry	13.00 9.75		14/10/93	9.79	7.71	G,a,75 / CB,4,35 / CB,d,24

t.o.c = top of casing
b.o.g = bottom of gully

KEY

Local Features,	Direction,	Distance
LO = large outcrop	u = up	10m
SO = small outcrop	d = down	50m
EB = exposed bedrock	a = across	200m
G = gully		etc
R = river		
CB = contour bund		
GW = grass waterway		
BH = big hill		
F = flay		
PW = ponded water		
A = Anthill		

PIEZO No.	DATUM LOC. AND ELEVATION Datum	Elevation (m agl)	Elevation (m acwd)	DRILLING LOGS (1 rod = 0.75m) Date	Total Depth (rods)	Water Strike (rods)	Basement hit (rods)	Time last rod (using DTMH) (mins)	POST DRILLING DIPPING Date	Total Depth (m bd)	Rest wl (m bd)	LOCAL FEATURES Feature, Direction, Distance (See Key Below)
M	t.o.c	0.15	3.30	09/10/93	3.00	dry	2.00 1·50	8.00	18/10/93	2.46	dry	CB,u,30 / CB,d,30
N1	t.o.c	0.15	15.78	19/10/93	2.00	dry	1.00 0·75		21/10/93	1.58	dry	LO,u,20
N2	t.o.c	0.10	14.36	19/10/93	12.00	dry	11.00 8·25	12.00	21/10/93	8.30	dry	LO,u,35 / CB,d,2
N3	t.o.c	0.15	12.90	19/10/93	8.00	dry	7.00 5·25	12.00	21/10/93	5.67	dry	LO,u,50
N4	t.o.c	0.15	11.17	18/10/93	14.00	dry	13.00 9·75		21/10/93	9.97	dry	LO,u,80 / CB,d,5
N5	t.o.c	0.15	7.70	18/10/93	19.00	dry	18.00 13·5	10.00	21/10/93	13.95	12.21	LO,u,130 / CB,u,4
N6	t.o.c	0.08	3.78	16/10/93	27.00	20.00	26.00 19·5	7.00	21/10/93	19.25	9.61	LO,u,230 / CB,u,20
O	t.o.c	0.14	22.92	01/10/93	11.00	dry	10.00 7·50	13.00	16/10/93	8.32	5.32	CB,d,4 / CB,u,45 / G,a,10
P	t.o.c	0.15	24.58	06/10/93	13.00	8.00	12.00 9·0	10.00	18/10/93	9.70	5.75	CB,u,5
Q1	t.o.c	0.16	26.24	06/10/93	20.00	16.00	19.00 14·25	8.00	18/10/93	12.80	4.11	By side of road that becomes a river
Q2	t.o.c	0.12	31.33	02/10/93	15.00	dry	14.00 10·5	14.00	18/10/93	11.00	10.47	By a path on the surface watershed
Q3	t.o.c	0.09	27.83	02/10/93	25.00	15.00	24.00 18·0	12.00	18/10/93	13.80	3.17	Out of surface water catchment
R	t.o.c	0.16	9.07	09/10/93	12.00	dry	11.00 8·25	8.00	16/10/93	9.09	2.56	CB,d,7 / CB,u,32 / GW,a,15
S	t.o.c	0.16	-1.90	16/10/93	10.00	9.00	9.00 6·75	10.00	18/10/93	7.04	2.74	CB,d,2 / G,a,25 / EB,u,10 / A,a,[illegible]
T	t.o.c	0.45	1.05	19/10/93	6.00	dry	5.00 3·75	12.00	21/10/93	4.28	dry	CB,u,10 / LO,u,150
U1	t.o.c	0.15	-1.23	20/10/93	5.00	dry	4.00 3·00	10.00	27/10/93	3.36	dry	R,d,100 / A,a,30 / EB,a,30
U2	t.o.c	0.05	-2.88	20/10/93	2.00	dry	1.00 0·75		27/10/93	0.51	dry	R,d,50 / EB,a,4
U3	t.o.c	0.10	-5.35	20/10/93	8.00	dry	7.00 5·25	12.00	27/10/93	9.00	dry	R,d,20
U4	t.o.c	0.05	-6.20	20/10/93	2.00	dry	1.00 0·75		27/10/93	1.50	dry	R,d,5
U5	b.o.g		-7.81	20/10/93	4.00	dry	3.00 2·25	12.00	27/10/93	2.70	dry	In river
U6	t.o.c	0.10	-6.22	20/10/93	20.00	dry	19.00 14·25	12.00	27/10/93	14.80	10.81	R,d,5
U7	t.o.c	0.10	-5.88	21/10/93	20.00	16.00	19.00 14·25	12.00	27/10/93	13.84	11.13	R,d,20
U8	t.o.c	0.00	-4.86	21/10/93	15.00	dry	14.00 10·5	8.00	27/10/93	10.46	6.81	R,d,50
U9	t.o.c	0.00	-3.12	21/10/93	6.00	dry	5.00 3·75	8.00	27/10/93	4.72	4.67	R,d,100
RC1	t.o.c	0.41	6.35	29/10/93	13.00	dry	10.00 7·50	15.00	08/11/93	8.50	dry	7" borehole in trench in contour bund
RC2	t.o.c	0.24	6.21	28/10/93	13.00	dry	10.00 7·50	15.00	08/11/93	8.04	dry	6" borehole in trench in contour bund
RC3	t.o.c	0.17	6.18	27/10/93	13.00	dry	9.00 6·75	11.00	08/11/93	7.00	dry	6" borehole in trench in contour bund
RC4	t.o.c	0.14	5.04	01/11/93	7.00	dry	7.00 5·25	6.00	08/11/93	5.98	5.85	Recharge trench,u,10
RC5	t.o.c	0.12	4.54	01/11/93	12.00	dry	12.00 9·00		08/11/93	8.44	dry	RT,u,20
RC6	t.o.c	0.13	3.91	01/11/93	12.00	dry	12.00 9·00		08/11/93	7.43	dry	RT,u,30 / CB,d,5 / WG,a,40
RC7	t.o.c	0.14	5.12	13/10/93	12.00	dry	6.00 4·5	10.00	08/11/93	8.90	dry	RT,a,50 / CB,u,8
RC8	t.o.c	0.14	4.42	30/10/93	10.00	dry	6.00 4·5	5.00	08/11/93	7.68	dry	CB,u,18
RC9	t.o.c	0.30	3.75	29/10/93	16.00	dry	16.00 12·0		08/11/93	12.45	9.88	CB,u,28 / CB,d,10 / WG,a,10

t.o.c = top of casing
b.o.g = bottom of gully

KEY

Local Features,	Direction,	Distance
LO = large outcrop	u = up	10m
SO = small outcrop	d = down	50m
EB = exposed bedrock	a = across	200m
G = gully		etc
R = river		
CB = contour bund		
GW = grass waterway		
BH = big hill		
F = flay		
PW = ponded water		
A = Anthill		

APPENDIX 4

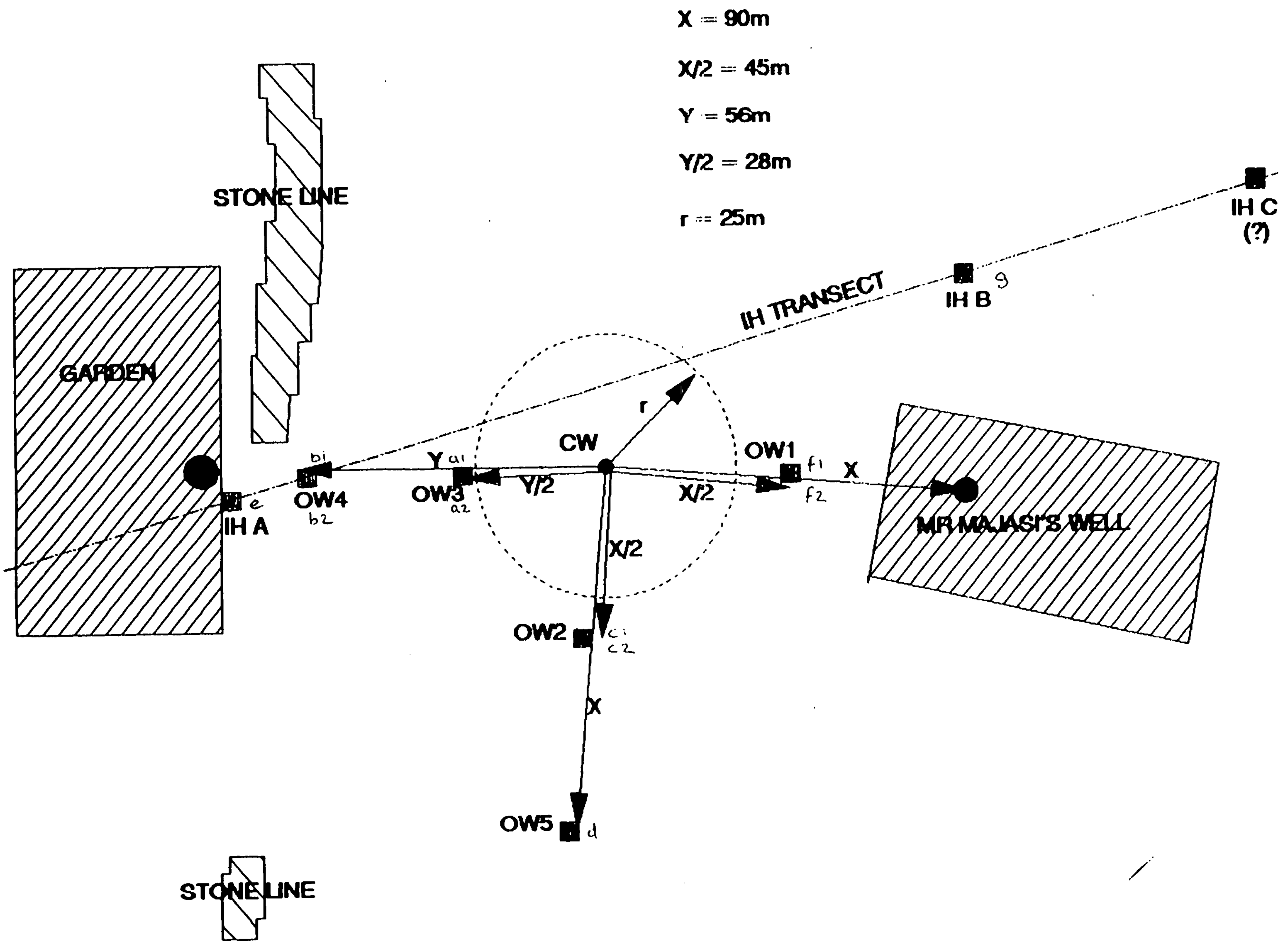


Fig Observation boreholes drilled adjacent to the Tamwa Collector Well (after Price, 1992).

Geological Log
Borehole No. A
Tamwa Collector Well Site.

Depth (m)	Description
0.00 - 0.75m	Dark olive green silt with included white nodules of calcrete. Some weathered black and white angular fragments with ochre iron staining.
0.75 - 1.50m	Dark olive green/brown clayey silt with some light brown clay. Very weathered micro-crystalline gneiss with dark green/brown and black amphibolite in white feldspar and quartz ground-mass.
1.50 - 2.25m	Angular fragments of fairly fresh to slightly weathered dark brown/black and white amphibolitic gneiss with weathered patches of white kaolin and orange iron oxide.
2.25 - 3.00m	Dark red brown to dark green amphibolitic gneiss, hard angular fragments with weathered surfaces. Some soft black manganese nodules. Some feldspar weathering to kaolin.
3.00 - 3.75m	Black fine grained amphibolitic gneiss, no mica, with dark red brown to ochre weathered faces and fractures. Feldspars fairly weathered to ochre brown along edges.
3.75 - 4.50m	Dark red black and dark green black amphibolitic gneiss, no mica, but some ochre weathering along fracture planes. Quartz fragments discoloured light brown.
4.50 - 5.25m	Dark brown black amphibolite, increasingly weathered with much white weathered feldspar, and smaller fragments of orange stained quartz. Some small soft nodules of manganese oxide. Ochre coloured along joints.
5.25 - 6.00m	Dark green black to red black medium to fine grained amphibolitic gneiss with white feldspars and light brown quartz. Some weathered partings with ochre stained fragment faces. Some manganese oxide nodules.
6.00 - 6.75m	Black green and red black fine fragments of fine grained amphibolitic gneiss. Many orange quartz fragments, white feldspars are moderately weathered to kaolinised in the larger fragments.
6.75 - 7.50m	Ochre brown fine grained mass of quartz and feldspar with fine black green amphibolitic gneiss fragments. Few large fragments and these show kaolinisation of feldspars.
7.50 - 8.25m	Ochre to dark brown silt to fine sand fragments of very weathered black green amphibolitic gneiss, few large fragments but these show weathering effects.
8.25 - 9.00m	Many block fragments of black amphibolitic gneiss with some red black weathering especially along joint/fracture faces. Some dark brown quartz, reduced white feldspars, degree of weathering apparently much less than above.
9.00 - 9.75m	Black fine to medium grained amphibolitic gneiss with dark red brown partings along joints. Some brown quartz fragments, smaller but more weathered than above.

9.75 - 10.5m Fine grained ochre to dark brown mass including black amphibolitic gneiss, dark red fragments, brown quartz and white vein quartz, very weathered.

10.5 - 11.25m Very weathered mass of fine grained white to red quartz and feldspar fragments, most of the mafic minerals have been oxidised to iron oxides.

11.25 - 12.00m 50% weathered black amphibolite with brown and white quartz, ochre clay with red brown partings. Some fairly large fragments of black amphibolite.

12.00 - 12.75m Very weathered black amphibolite with much brown stained and white vein quartz, the latter from fractures.

12.75 - 13.50m Weathered fractured amphibolite with much vein quartz stained orange brown to white olive.

13.50 - 14.25m Zone of iron oxidation with much ochre/orange iron oxide within vuggy weathered amphibolite. Much dark red to white vein quartz, possibly the lower edge of a shatter zone.

14.25 - 15.00m Still in the shatter zone with much dark red to brown fault quartz with black amphibolite gneiss that is sometimes weathered dark red.

Geological Log
Borehole No 4
Tamwa Collector Well Site

Depth (m)	Description
0.00 - 0.75m	Very weathered black brown to ochre silty clay with little weathered black amphibolite, some white partially weathered feldspars.
0.75 - 1.50m	Hard dark brown silty clay that disintegrates on addition of water with ochre fine sand of weathered amphibolite.
1.50 - 2.25m	Fairly well weathered dark black brown fine to medium amphibolite with white feldspars weathering to kaolin.
2.25 - 3.00m	Fine grained weathered ochre to dark brown fragments with about 25% large fragments of black and white amphibolitic gneiss with dark red weathered partings and feldspars weathered to kaolin.
3.00 - 3.75m	Black amphibolitic gneiss, reduced formation of kaolin but increased formation of orange iron oxides.
3.75 - 4.50m	Large blocky fragments of black fine to medium grained amphibolite, some kaolinisation of feldspars, some dark red to ochre iron oxides mainly on fracture planes.
4.50 - 5.25m	Large blocky fragments of black fine to medium grained amphibolite, some dark red iron oxidation.
5.25 - 6.00m	Large blocky fragments of black fine to medium amphibolite, with ochre to dark red iron oxidation on surfaces. Occasional lumps of very weathered biscuit form ochre and light grey clay rich layers alternating with hard gneiss?
6.00 - 6.75m	Well weathered black amphibolite, with much red brown quartz, few large fragments, some vuggy manganiferous lumps.
6.75 - 7.50m	Weathered black amphibolite with much orange brown quartz and iron staining.
7.50 - 8.25m	Weathered black amphibolite with much orange brown iron stained quartz and dark red brown oxidised partings. Some kaolinised feldspars.
8.25 - 9.00m	Well weathered fine grained black amphibolite with much orange iron oxide.
9.00 - 9.75m	Black amphibolitic gneiss with white quartzitic partings, some orange iron oxide partings.
9.75 - 10.50m	Water bearing weathered black amphibolite with quartzitic horizons, some iron oxide staining, some indication of fractured fragments ie cracked quartz layers.
10.50 - 11.25m	Weathered black amphibolite with orange iron oxide staining, some vein quartz.
11.25 - 12.00m	Weathered black amphibolite with orange iron oxide staining, much white vein quartz.
12.00 - 12.75m	Less weathered black amphibolite with orange iron oxide stained partings, with little vein quartz.

12.75 - 13.50m Fairly weathered black amphibolite with some orange iron oxide staining along fracture planes.

13.50 - 14.25m Fairly weathered black amphibolite, some vein quartz, much orange iron oxide staining.

14.25 - 15.00m Well weathered black amphibolite, some orange vein quartz and much orange iron oxide staining.

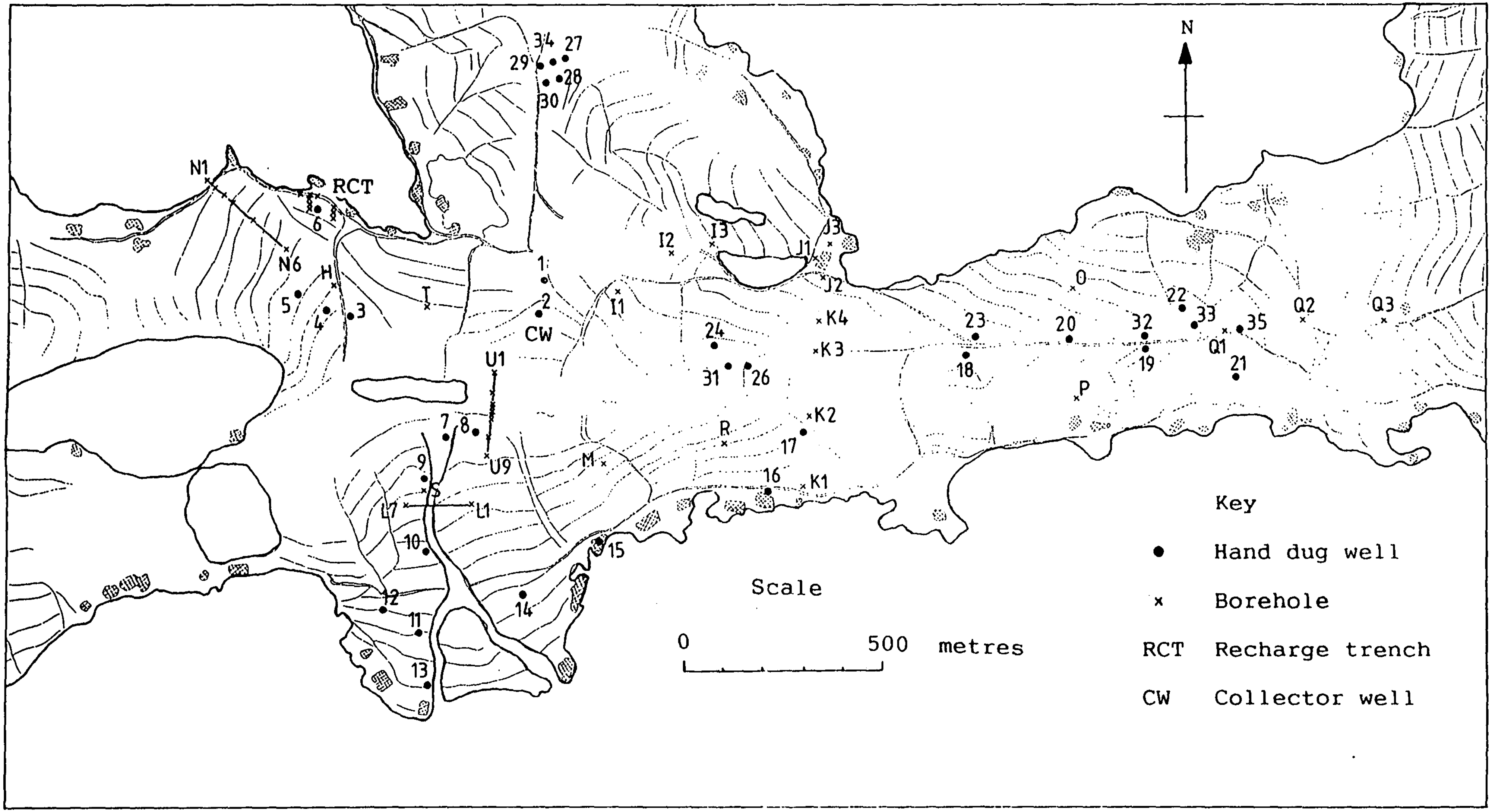


Fig Tamwa study area -
hand dug well and borehole location map

Borehole No. **H**
Date drilled **28/9**

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	weathered rock
	2	1.50	30 secs	
	3	2.25	30 secs	
	4	3.00	30 secs	
	5	3.75	30 secs	
	6	4.50	30 secs	
	7	5.25	30 secs	
	8	6.00	30 secs	
	9	6.75	30 secs	
	10	7.50	30 secs	
	11	8.25	30 secs	
	12	9.00	30 secs	weathered rock
	13	9.75	10 mins	bedrock
	14	10.50	10 mins	water struck
	15	11.25	10 mins	
	16	12.00	10 mins	
	17	12.75	10 mins	
	18	13.50	10 mins	
	19	14.25	10 mins	
	20	15.00	10 mins	bedrock

Rest water level 8.30 m

Borehole No. I1
Date drilled 29/9

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75		clay
DB	2	1.50		hard and soft bands
DB	3	2.25		hard and soft bands
DB	4	3.00		hard and soft bands
DB	5	3.75		hard and soft bands
DHH	6	4.50		hard
DHH	7	5.25		hard
DHH	8	6.00		hard
DHH	9	6.75		hard
DHH	10	7.50		hard
DHH	11	8.25		hard

Borehole No. 12
Date drilled 30/9

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75		soil clay
	2	1.50		soil clay
	3	2.25		soil clay
	4	3.00		soil clay
	5	3.75		weathered
	6	4.50		weathered
	7	5.25		weathered
	8	6.00		weathered
	9	6.75		hard
	10	7.50		hard
	11	8.25		hard
	12	9.00		hard
	13	9.75		hard
	14	10.50		hard
	15	11.25		hard
				No water

Borehole No. 13
Date drilled 30/9

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	5	clay
DB	2	1.50	6	clay
DB	3	2.25	6	clay
DB	4	3.00	6	clay
DB	5	3.75	2	soft/weathered
DB	6	4.50	2	soft/weathered
DB	7	5.25	2	soft/weathered
DB	8	6.00	2	soft/weathered
DB	9	6.75	2	soft/weathered
DB	10	7.50	3	soft/weathered
DB	11	8.25	3	soft/weathered
DB	12	9.00	3	soft/weathered
DHH	13	9.75	3	soft/weathered
DHH	14	10.50	3	soft/weathered
DHH	15	11.25	3	soft
DHH	16	12.00	3	soft
DHH	17	12.75	3	soft
DHH	18	13.50	3	soft
DHH	19	14.25	5	soft
DHH	20	15.00	4	soft
DHH	21	15.75	4	soft
DHH	22	16.50	4	soft
DHH	23	17.25	4	soft
DHH	24	18.00	5	soft
DHH	25	18.75	5	soft/weathered
DHH	26	19.50	9	hard
DHH	27	20.25	9	hard

Borehole No. J2
Date drilled 30/9

Drill Type	**Rod No.**	**Depth metres**	**Penetration time (mins)**	**Geology**
DB	1	0.75	30 secs	soil
DB	2	1.50	30 secs	soil
DHH	3	2.25	?	?
DHH	4	3.00	12 mins	hard

Basement at 1.90 m, dry

Borehole No. K1
Date drilled 8/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DB	2	1.50	3 mins	clay
DB	3	2.25	10 mins	clay
DB	4	3.00	? mins	clay
DB	5	3.75	4 mins	clay
DB	6	4.50	1 mins	weathered
DB	7	5.25	4 mins	banded clay
DB	8	6.00	2 mins	weathered
DB	9	6.75	5 mins	weathered
DB	10	7.50	2 mins	weathered
DB	11	8.25	2 mins	weathered
DB	12	9.00	3 mins	weathered
DHH	13	9.75	3 mins	weathered
DHH	14	10.50	5 mins	hard banded
DHH	15	11.25	8 mins	hard

Basement at 10.50 m, dry.

Borehole No. K1D
Date drilled 25/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DB	2	1.50	6 mins	clay
DB	3	2.25	9 mins	clay
DB	4	3.00	12 mins	clay
DB	5	3.75	7 mins	clay
DB	6	4.50	3 mins	clay
DB	7	5.25	1 mins	weathered
DB	8	6.00	1 mins	banded soft and hard
DB	9	6.75	1 mins	banded soft and hard
DB	10	7.50	2 mins	banded soft and hard
DB	11	8.25	3 mins	banded soft and hard
DB	12	9.00		banded soft and hard
DDH	13	9.75	3 mins	hard-very banded
DDH	14	10.50	4 mins	hard-very banded
DDH	15	11.25	5 mins	hard-very banded
DDH	16	12.00	5 mins	hard-very banded
DDH	17	12.75	3 mins	hard-very banded
DDH	18	13.50	4 mins	hard-very banded
DDH	19	14.25	6 mins	hard-very banded
DDH	20	15.00	5 mins	hard-very banded
DDH	21	15.75	3 mins	hard-very banded
DDH	22	16.50	3 mins	hard-very banded
DDH	23	17.25	3 mins	hard-very banded
DDH	24	18.00	4 mins	hard-very banded
DDH	25	18.75	5 mins	hard-very banded
DDH	26	19.50	3 mins	hard-very banded
DDH	27	20.25	3 mins	hard-very banded
DDH	28	21.00	5 mins	hard-very banded
DDH	29	21.75	5 mins	hard-very banded
DDH	30	22.50	6 mins	hard-very banded
DDH	31	23.25	4 mins	hard-very banded
DDH	32	24.00	3 mins	hard-very banded

Borehole No. K3
Date drilled 6/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DB	2	1.50	30 secs	weathered
DB	3	2.25	1 mins	weathered
DB	4	3.00	8 mins	hard clay
DB	5	3.75	1 mins	weathered
DB	6	4.50	1 mins	weathered
DB	7	5.25	2 mins	weathered
DB	8	6.00	1.5 mins	weathered
DB	9	6.75		weathered
DB	10	7.50	1.5 mins	weathered
DB	11	8.25	1 mins	banded
DB	12	9.00	1 mins	banded
DB	13	9.75		banded
DDH	14	10.50	6 mins	banded
DDH	15	11.25	8 mins	hard banded
DDH	16	12.00	9 mins	hard

Basement at 9.75 m, water struck 6.75 m, rest level 3.34 m.

Borehole No. K3D
Date drilled 26/10

Drill Type	**Rod No.**	**Depth metres**	**Penetration time (mins)**	**Geology**
DB	1	0.75	30 secs	soil
DB	2	1.50	30 secs	soil
DB	3	2.25	2 mins	weathered
DB	4	3.00	1 mins	weathered
DB	5	3.75	1 mins	weathered
DB	6	4.50	1 mins	weathered
DB	7	5.25	1 mins	weathered
DB	8	6.00	1 mins	weathered
DB	9	6.75	1 mins	weathered
DB	10	7.50	1 mins	weathered
DB	11	8.25	2 mins	weathered
DDH	12	9.00		weathered
DDH	13	9.75	4 mins	hard
DDH	14	10.50	4 mins	hard
DDH	15	11.25	10 mins	very hard
DDH	16	12.00	14 mins	very hard
DDH	17	12.75	11 mins	very hard
DDH	18	13.50	10 mins	very hard
DDH	19	14.25	12 mins	very hard
DDH	20	15.00	15 mins	very hard
DDH	21	15.75	12 mins	very hard
DDH	22	16.50	12 mins	very hard
DDH	23	17.25	13 mins	very hard
DDH	24	18.00	13 mins	very hard
DDH	25	18.75	16 mins	very hard

Basement at 9.00 m, dry.

Borehole No. L1
Date drilled 9/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	clay
DB	2	1.50	8 min	clay
DB	3	2.25	7 min	clay
DB	4	3.00	8 min	clay
DB	5	3.75	6 min	clay
DB	6	4.50	3 min	clay
DB	7	5.25	1 min	clay
DB	8	6.00	2 min	banded
DB	9	6.75	2 min	clay
DB	10	7.50	2 min	clay
DB	11	8.25	2 min	clay
DB	12	9.00	4 min	clay
DB	13	9.75	6 min	clay
DB	14	10.50	3 min	clay
DB	15	11.25	6 min	clay
DB	16	12.00	6 min	clay
DB	17	12.75	4 min	clay
DB	18	13.50	4 min	clay
DB	19	14.25	4 min	clay
DB	20	15.00	5 min	clay
DB	21	15.75	8 min	clay
DB	22	16.50	4 min	weathered
DB	23	17.25	4 min	weathered
DDH	24	18.00	4 min	weathered
DDH	25	18.75	6 min	hard
DDH	26	19.50	8 min	hard

Basement at 18.75 m, water struck at 12.00 m.

Borehole No. N1
Date drilled 19/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DHH	2	1.50	1.5 mins	hard rock.

Dry.

Borehole No. N2
Date drilled 19/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	1 mins	soil
DB	2	1.50	1 mins	weathered
DB	3	2.25	1 mins	weathered
DB	4	3.00	1 mins	weathered
DB	5	3.75	1 mins	weathered
DB	6	4.50	1 mins	weathered
DB	7	5.25	1 mins	weathered
DB	8	6.00	1 mins	weathered
DB	9	6.75		hard and soft bands
DDH	10	7.50	2 mins	hard and soft bands
DDH	11	8.25	3 mins	hard and soft bands
DDH	12	9.00	12 mins	hard

Basement at 8.25 m.

Borehole No. Q1
Date drilled

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DB	2	1.50	1 mins	weathered
DB	3	2.25	1 mins	weathered
DB	4	3.00	1 5 mins	weathered
DB	5	3.75	3 mins	weathered
DB	6	4.50	2 mins	weathered
DB	7	5.25	6 mins	weathered
DB	8	6.00		weathered
DB	9	6.75	4 mins	weathered
DB	10	7.50	4 mins	weathered
DB	11	8.25	1 mins	weathered
DB	12	9.00	3 mins	weathered
DB	13	9.75		weathered
DB	14	10.50	2 mins	banded
DB	15	11.25	3 mins	banded
DDH	16	12.00	2 mins	banded
DDH	17	12.75	8 mins	banded
DDH	18	13.50	4 mins	banded
DDH	19	14.25	5 mins	banded
DDH	20	15.00	8 mins	hard

Basement at 14.25 m.

Borehole No. Q2
Date drilled 2/10

Drill Type	**Rod No.**	**Depth metres**	**Penetration time (mins)**	**Geology**
DB	1	0.75	30 secs	soil
DB	2	1.50	30 secs	soil
DB	3	2.25		weathered
DB	4	3.00		weathered
DB	5	3.75	2 mins	weathered
DB	6	4.50	2 mins	weathered
DB	7	5.25	2 mins	weathered
DB	8	6.00	8 mins	weathered
DDH	9	6.75	2 mins	weathered
DDH	10	7.50	2 mins	weathered
DDH	11	8.25	2 mins	weathered
DDH	12	9.00	7 mins	hard and soft bands
DDH	13	9.75	7 mins	hard and soft bands
DDH	14	10.50	9 mins	hard and soft bands
DDH	15	11.25	14 mins	hard

Basement at 10.50 m, dry.

Borehole No. Q3
Date drilled

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DB	2	1.50	30 secs	soil
DB	3	2.25	30 secs	weathered
DB	4	3.00		very soft
DB	5	3.75		very soft
DB	6	4.50	4 mins	very soft
DB	7	5.25	5 mins	very soft
DB	8	6.00		very soft
DB	9	6.75	3 mins	very soft
DB	10	7.50	4 mins	very soft
DB	11	8.25	4 mins	very soft
DB	12	9.00	4 mins	very soft
DB	13	9.75	4 mins	very soft
DDH	14	10.50	3 mins	very soft
DDH	15	11.25	3 mins	very soft
DDH	16	12.00	3 mins	very soft
DDH	17	12.75	3 mins	very soft
DDH	18	13.50	4 mins	very soft
DDH	19	14.25	4 mins	very soft
DDH	20	15.00	6 mins	very soft
DDH	21	15.75	4 mins	very soft
DDH	22	16.50	4 mins	very soft
DDH	23	17.25	3 mins	very soft
DDH	24	18.00	3 mins	weathered
DDH	25	18.75	12 mins	hard

Borehole No. U2
Date drilled

Drill Type	**Rod No.**	**Depth metres**	**Penetration time (mins)**	**Geology**
DB	1	0.75	30 secs	weathered
DDH	2	1.50	1.5 mins	hard rock

Borehole No. U3
Date drilled 20/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DB	2	1.50	3 mins	clay
DB	3	2.25	8 mins	clay
DB	4	3.00	6 mins	clay
DB	5	3.75	1 mins	weathered
DB	6	4.50	1 mins	weathered
DB	7	5.25	1 mins	weathered
DDH	8	6.00	12 mins	hard

Basement at 5.25 m, dry.

Borehole No. U9
Date drilled

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
DB	1	0.75	30 secs	soil
DB	2	1.50	1 mins	weathered
DB	3	2.25	1 mins	weathered
DB	4	3.00	1 mins	weathered
DDH	5	3.75	4 mins	hard
DDH	6	4.50	8 mins	hard

Basement at 3.75 m.

Borehole No. RC2
Date drilled 28/10

Drill Type	Rod No.	Depth metres	Penetration time (mins)	Geology
8"DB	1	0.75	2 mins	soil
8"DB	2	1.50	2 mins	weathered
8"DB	3	2.25	2 mins	weathered
8"DB	4	3.00	8 mins	weathered
8"DB	5	3.75	4 mins	weathered
8"DB	6	4.50	4 mins	weathered
8"DB	7	5.25	3 mins	weathered
8"DB	8	6.00	4 mins	weathered
8"DB	9	6.75	4 mins	weathered
8"DB	10	7.50		weathered
5"DDH	11	8.25	15 mins	hard
5"DDH	12	9.00	15 mins	hard
5"DDH	13	9.75	15 mins	hard

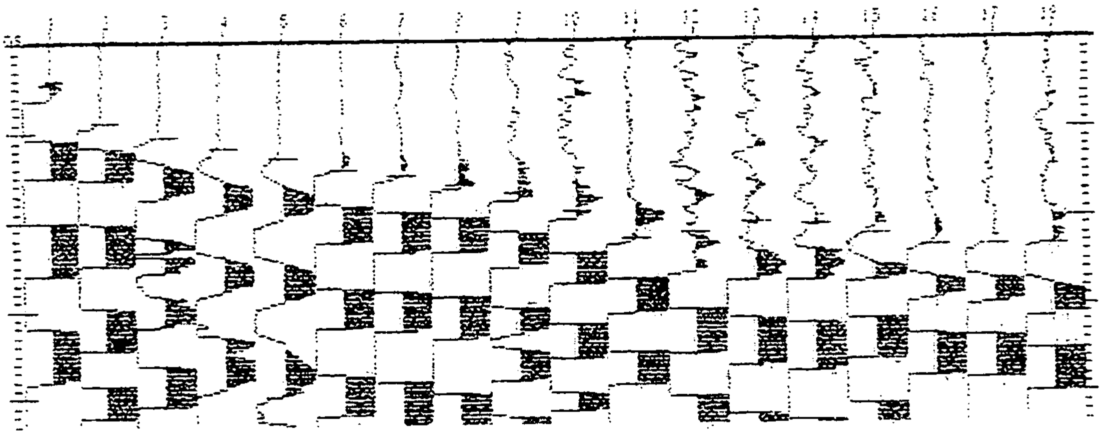
Cased to 8 m, gravel packed with sump to 10.25 m.
Basement at 7.50 m.

APPENDIX 5

Profile ID: TAMWAI
Project: SUST
Customer: ODA
Cust. ref.: ODA
Operator: DUNC AND JEFF
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/18
Created: 08:46
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

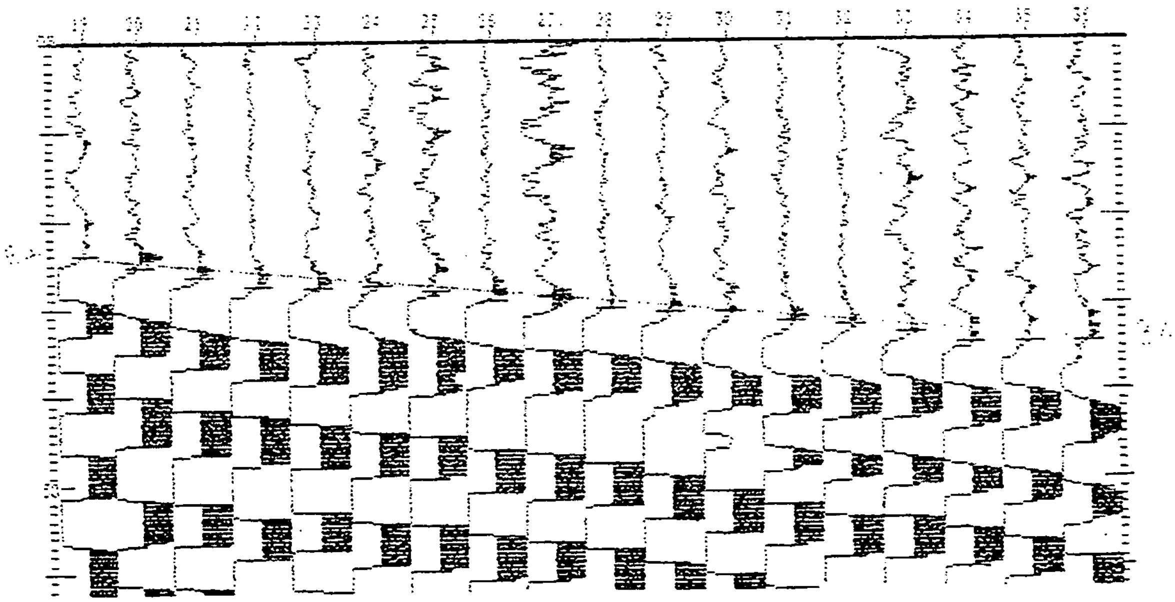
Channel:1



Profile ID: TAMWAI
Project: SUST
Customer: ODA
Cust. ref.: ODA
Operator: DUNC AND JEFF
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/18
Created: 08:46
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.9 m

Channel:2



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Project:	BUST	Date:	94/02/18
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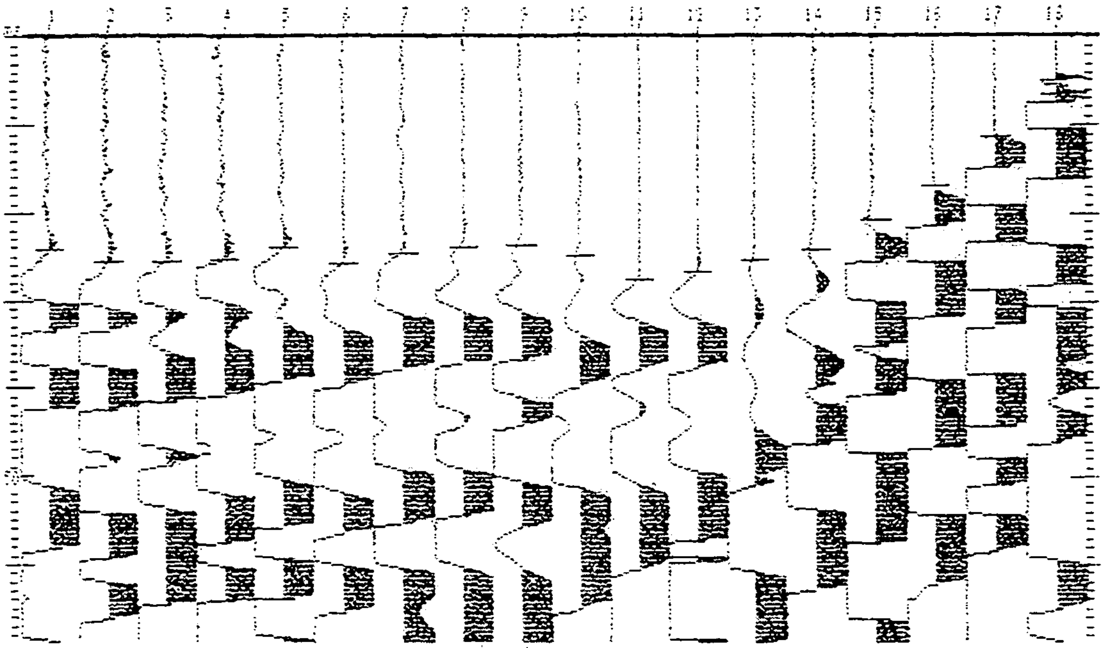
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	DUNG AND JEFF	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:0



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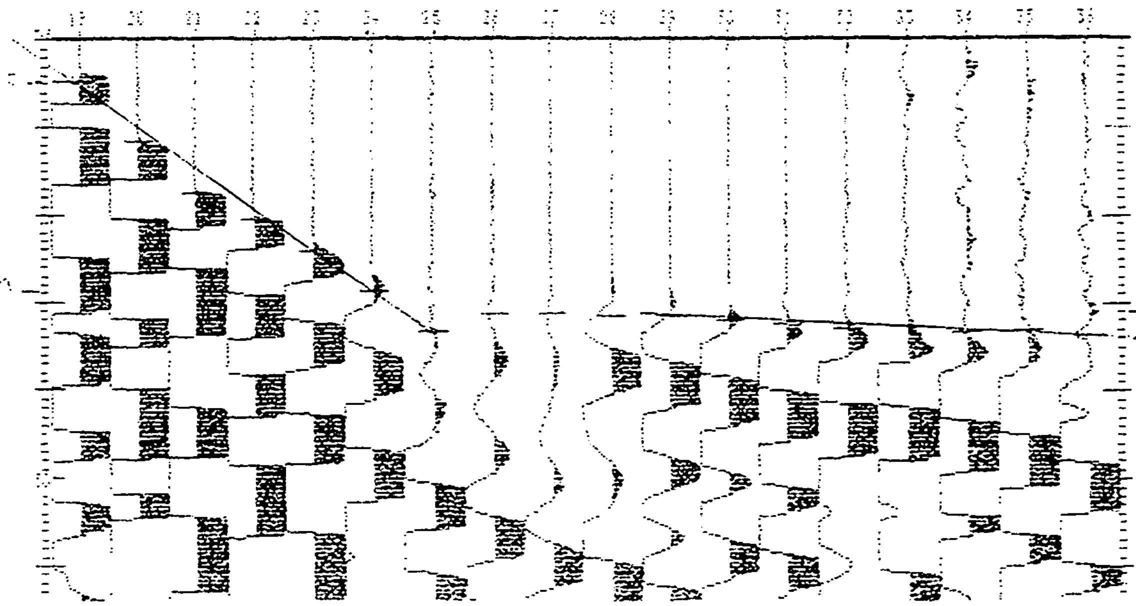
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	DUNG AND JEFF	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



Profile ID:	TAMMA1	Method:	Automatic
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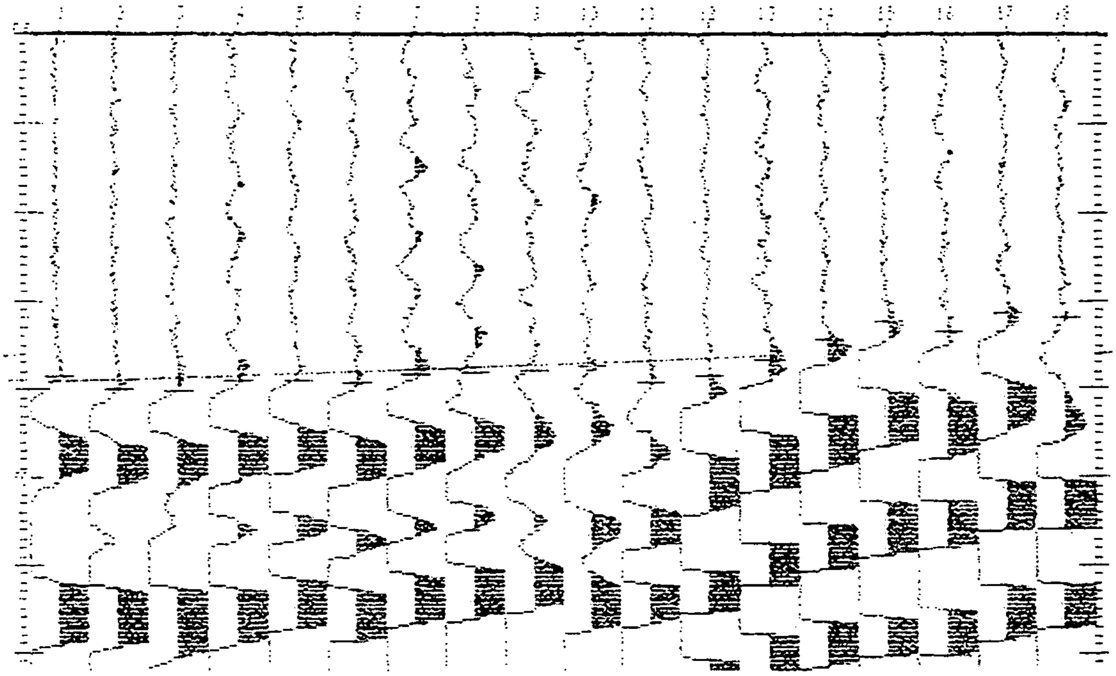
Cust. ref.:	CDA	Geoph. spacing:	54.0 m
Operator:	DUNC AND JEFF	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



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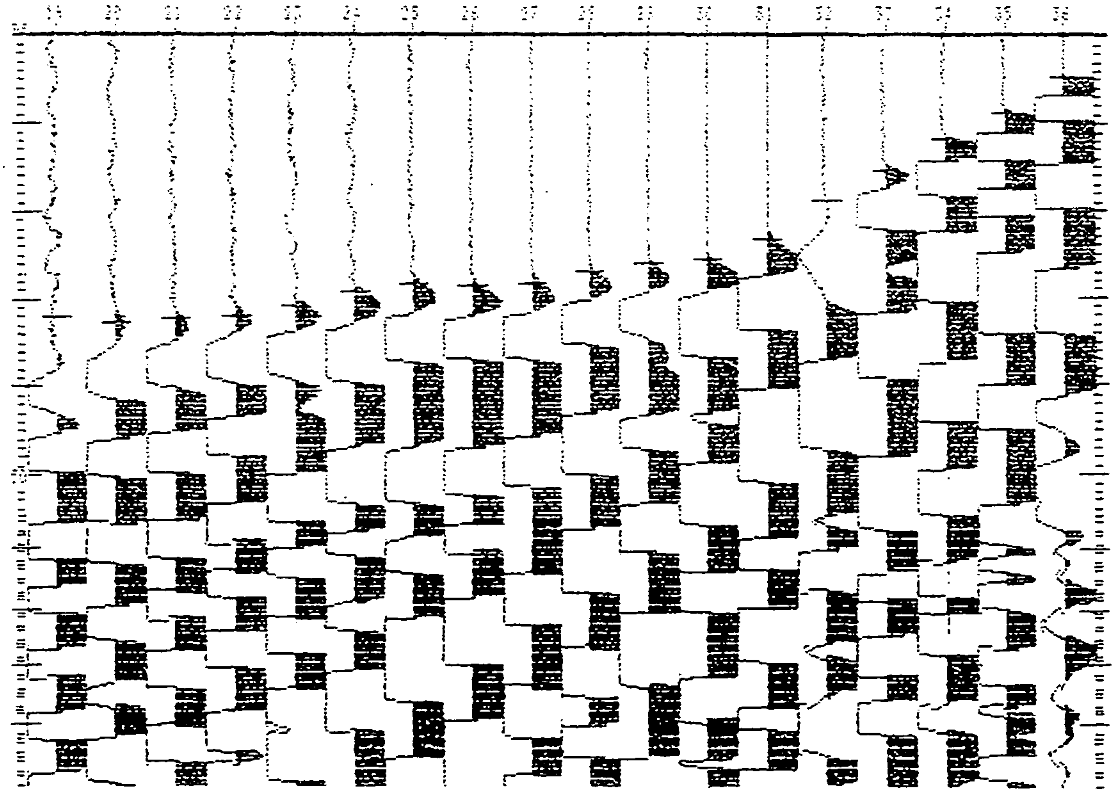
Project:	8081	Date:	94/02/15
Customer:	CDA	Created:	08:46
Cust. ref..:	CP4	Geoph. spacing:	54.0 m
Operator:	DUNC AND JEFF	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



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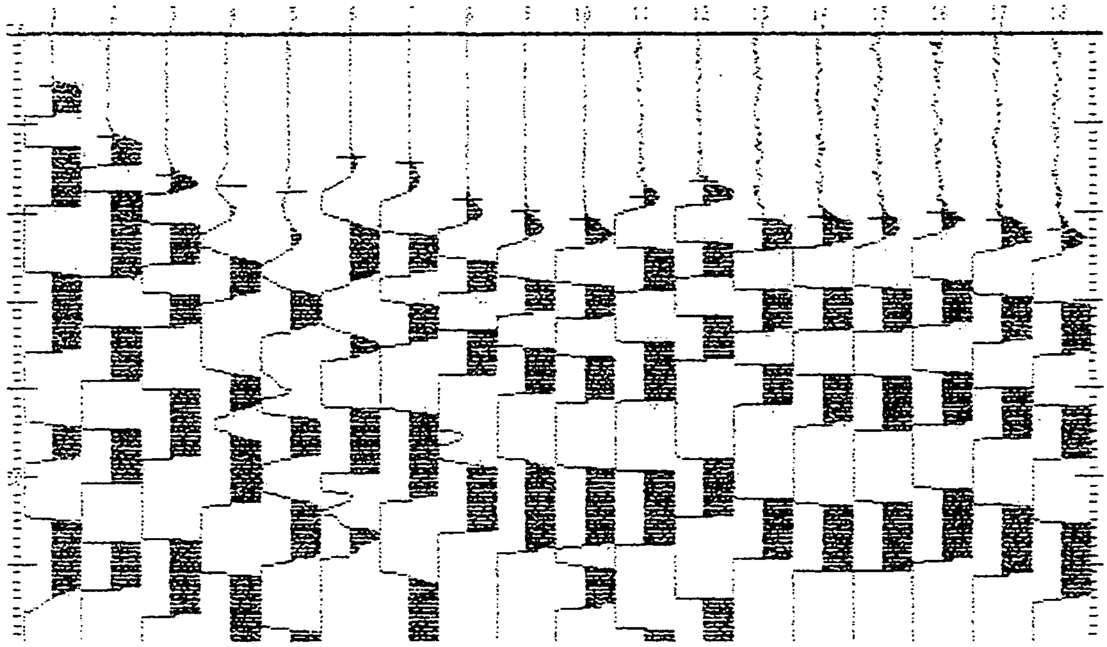
Project:	BUST	Date:	84/02/10
Customer:	ODA	Created:	12:40
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	DUNO AND JEFF	Shot spacing:	3.0 m
Comments:	BUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



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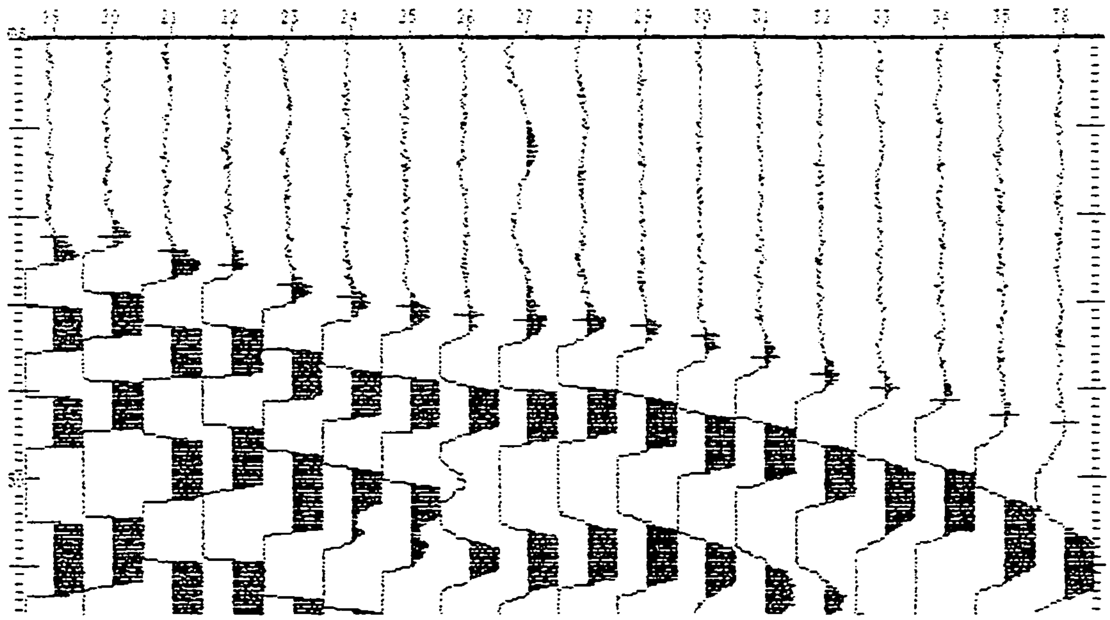
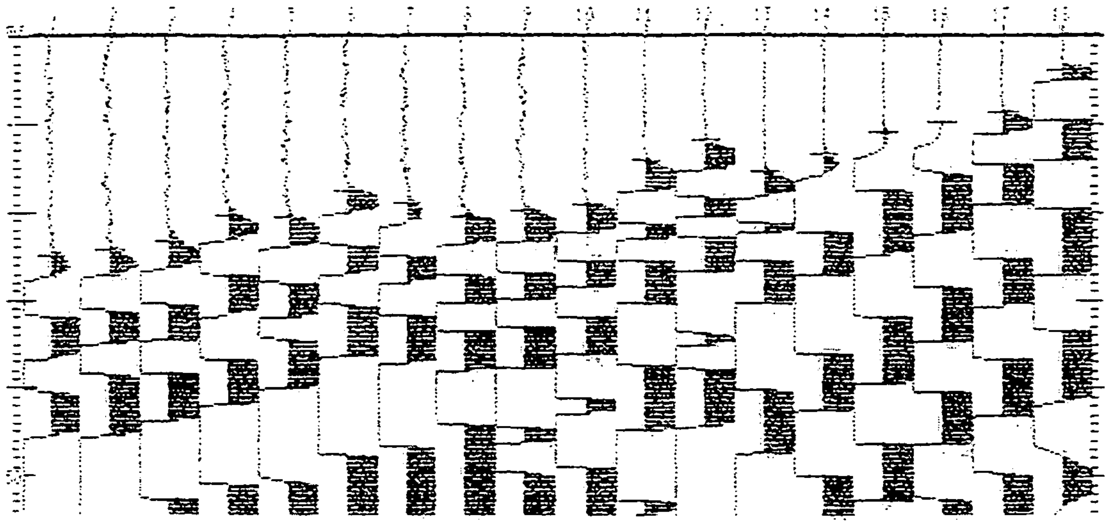
Project:	BUST	Date:	84/02/10
Customer:	ODA	Created:	12:40
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	DUNO AND JEFF	Shot spacing:	3.0 m
Comments:	BUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



Profile ID: TAMWA2 Method: Automatic
Project: BUFT Date: 94/02/10
Customer: ODA Created: 12:40
Cust. ref.: ODA Geoph. spacing: 54.0 m
Operator: DUNO AND JEFF Shot spacing: 3.0 m
Comments: SUNNY WINDY METAL PLATE Start offset: 1.5 m

Channel:2



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Profile ID:	TAMWA2	Method:	Automatic
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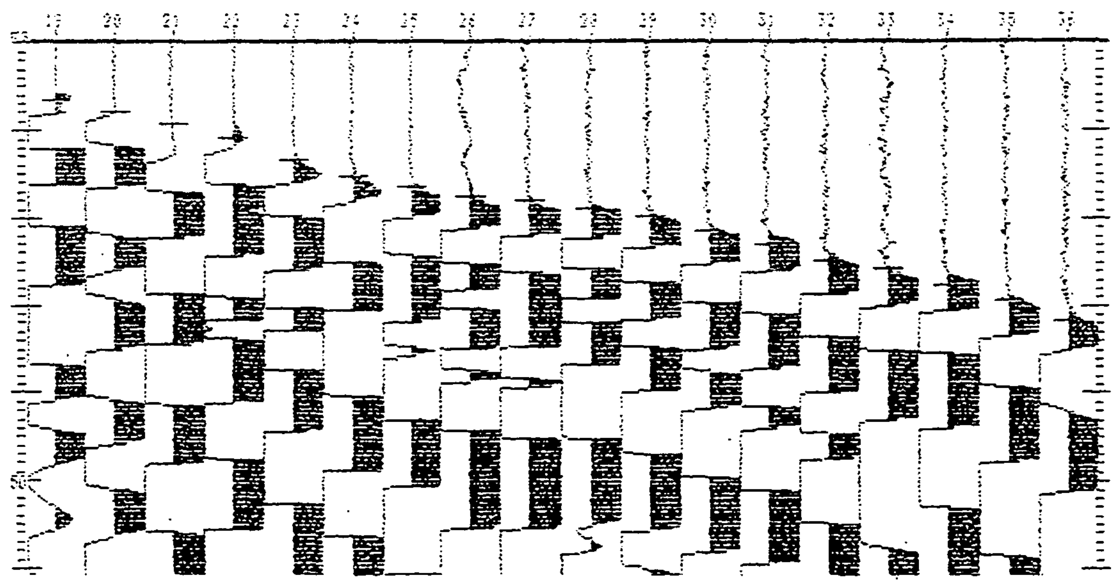
Customer:	ODA	Created:	12:40
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	DUNO AND JEFF	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:2



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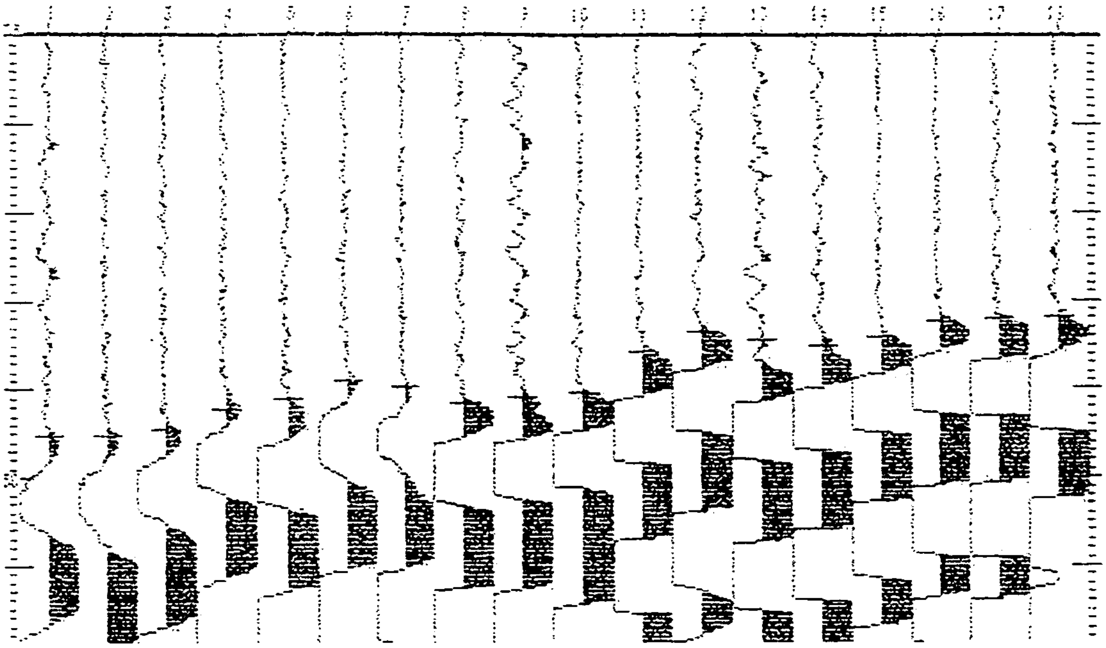
Comments: SUNNY WINDY METAL PLATE

Channel:0



Profile ID: TAMWWA2
Project: BUST
Customer: ODA
Cust. ref.: ODA
Operator: DUNO AND JEFF
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
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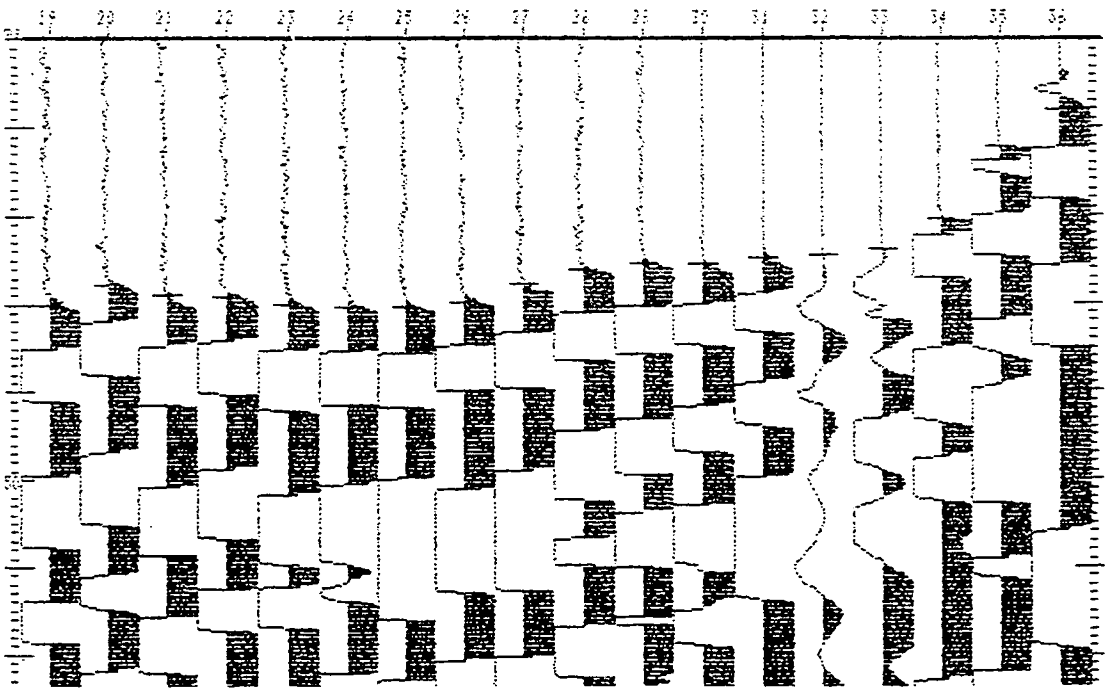
Created: 12:40
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

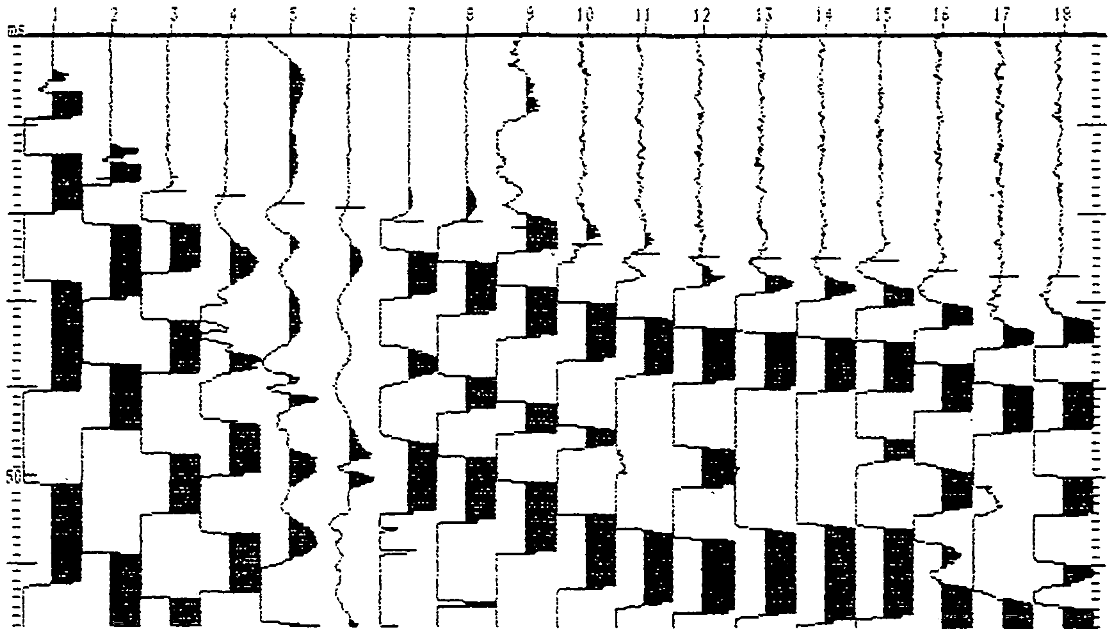
Channel:0



Profile ID: TAMWA3/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: PEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 09:09
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

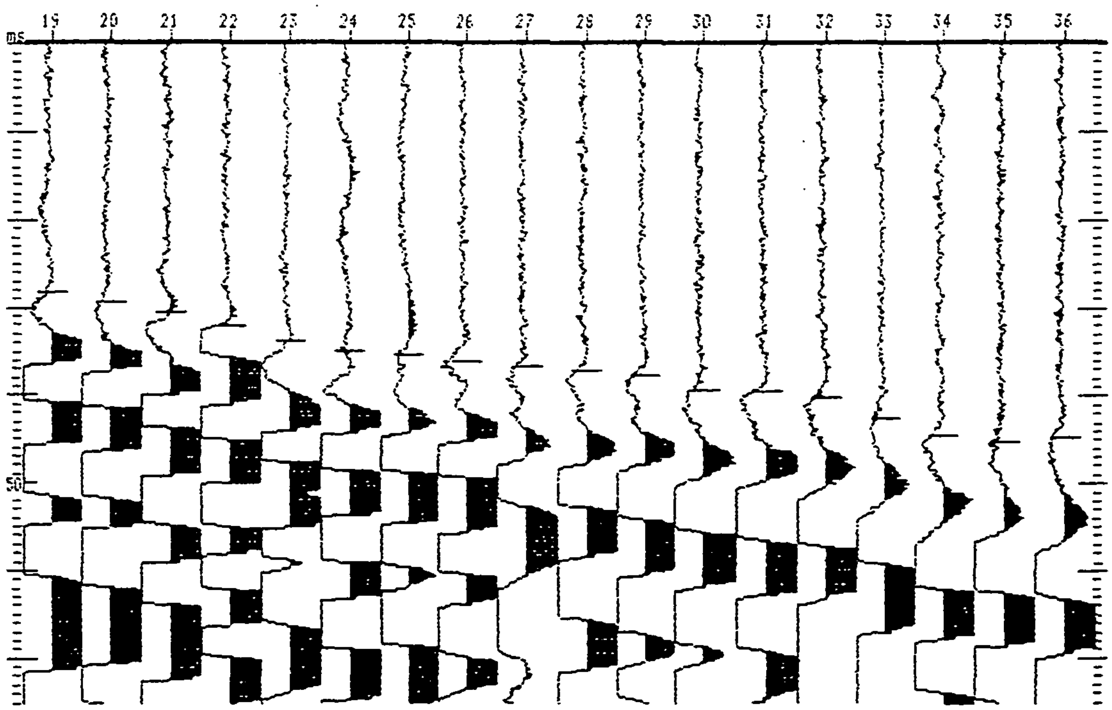
Channel:1



Profile ID: TAMWA3/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: PEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 09:09
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

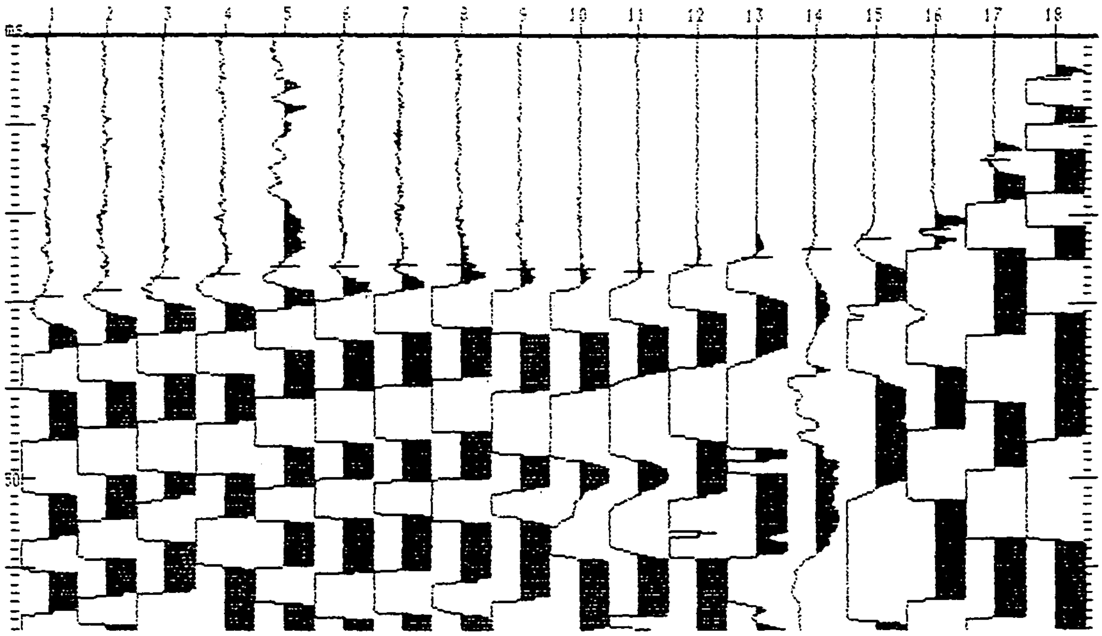
Channel:1



Profile ID: TAMWA3/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: PEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 09:09
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

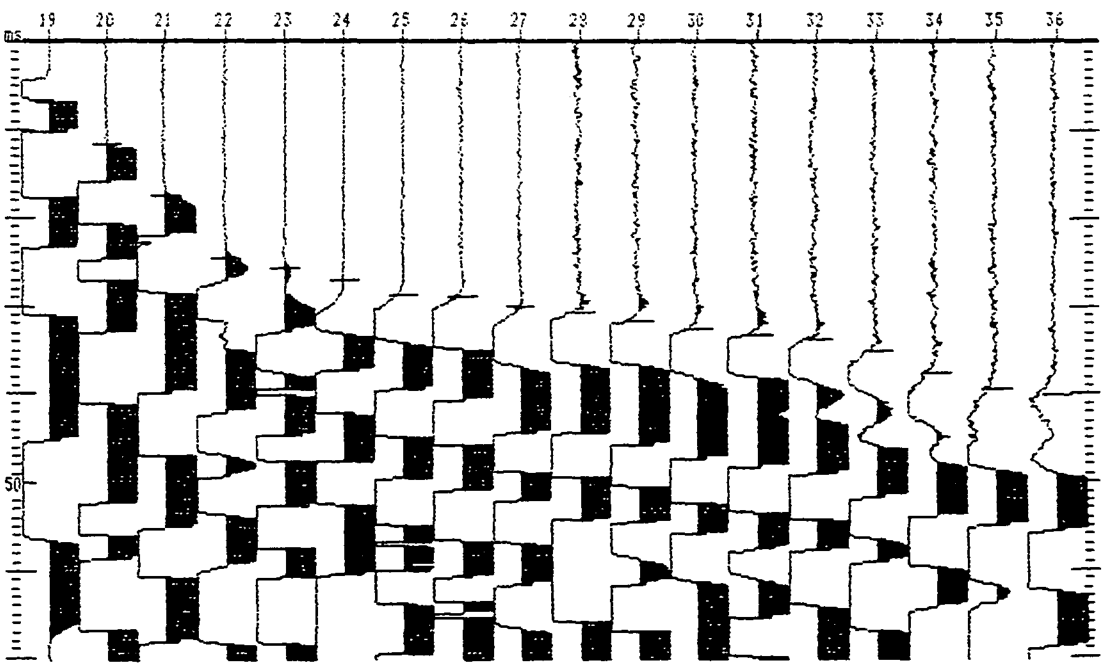
Channel:2



Profile ID: TAMWA3/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: PEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 09:09
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

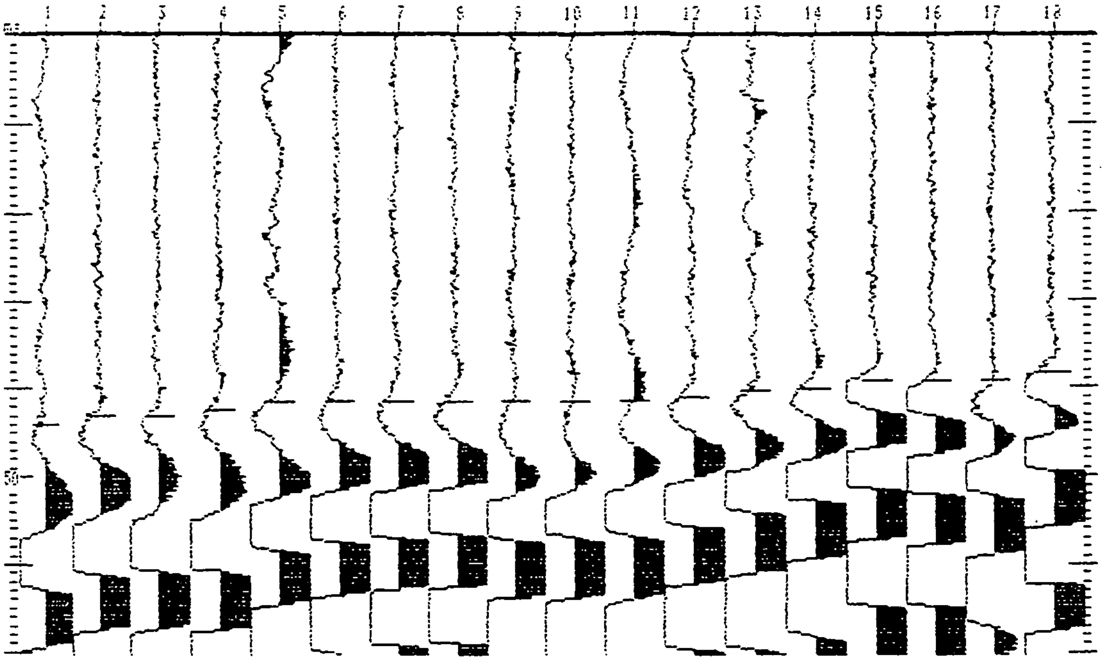
Channel:2



Profile ID: TAMWA3/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: PEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 09:09
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

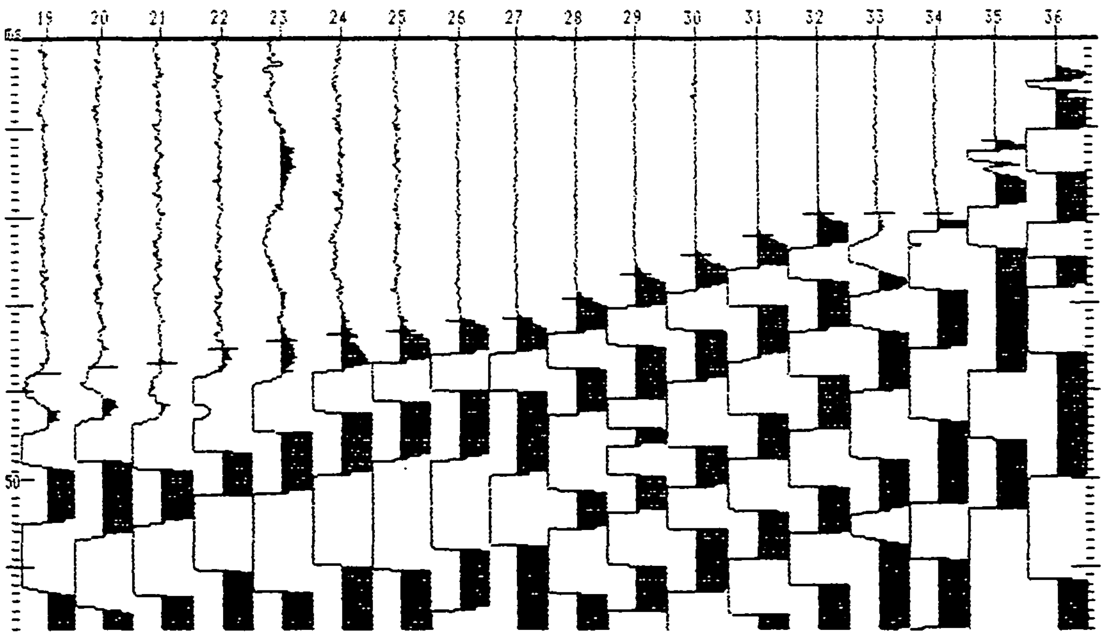
Channel:3



Profile ID: TAMWA3/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: PEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 09:09
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

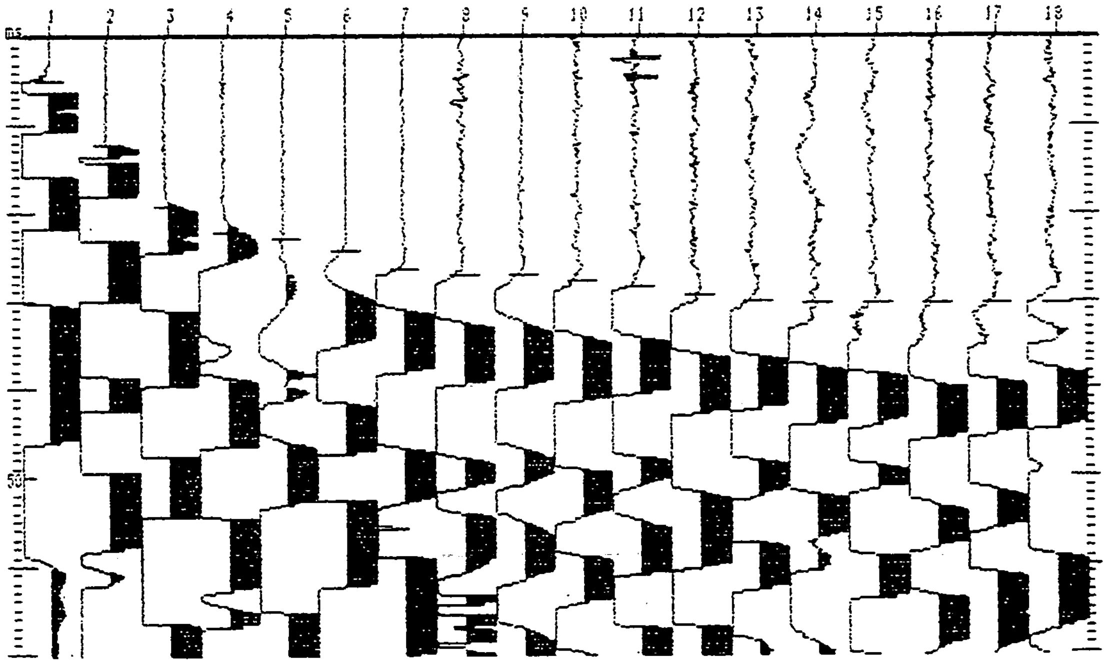
Channel:3



Profile ID: TAMWA4/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 11:11
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

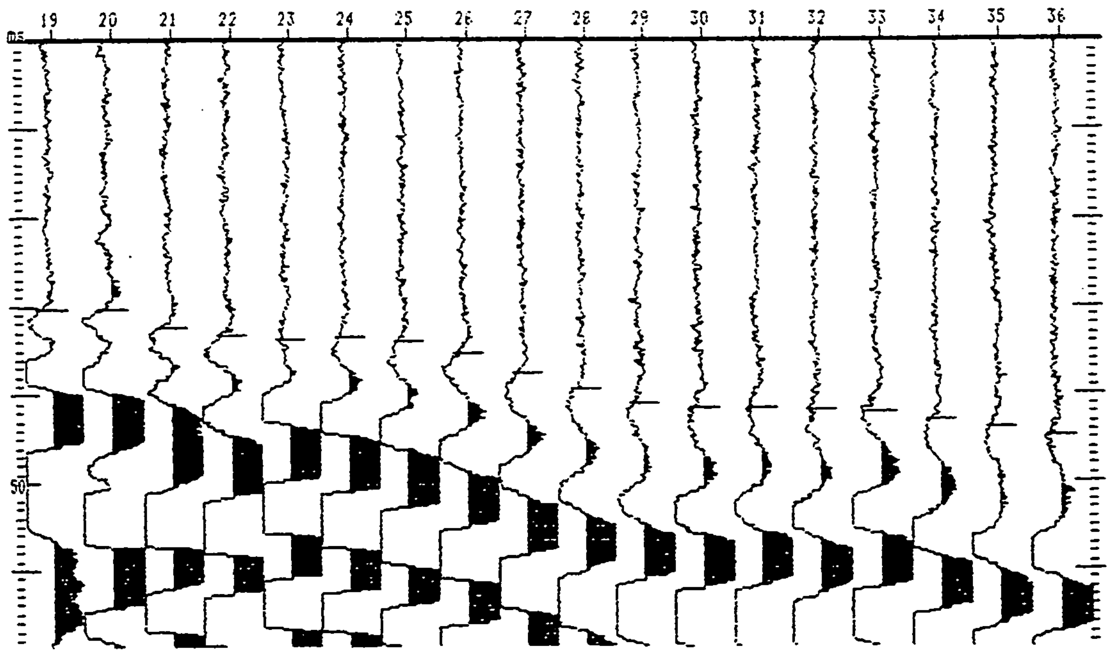
Channel:1



Profile ID: TAMWA4/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

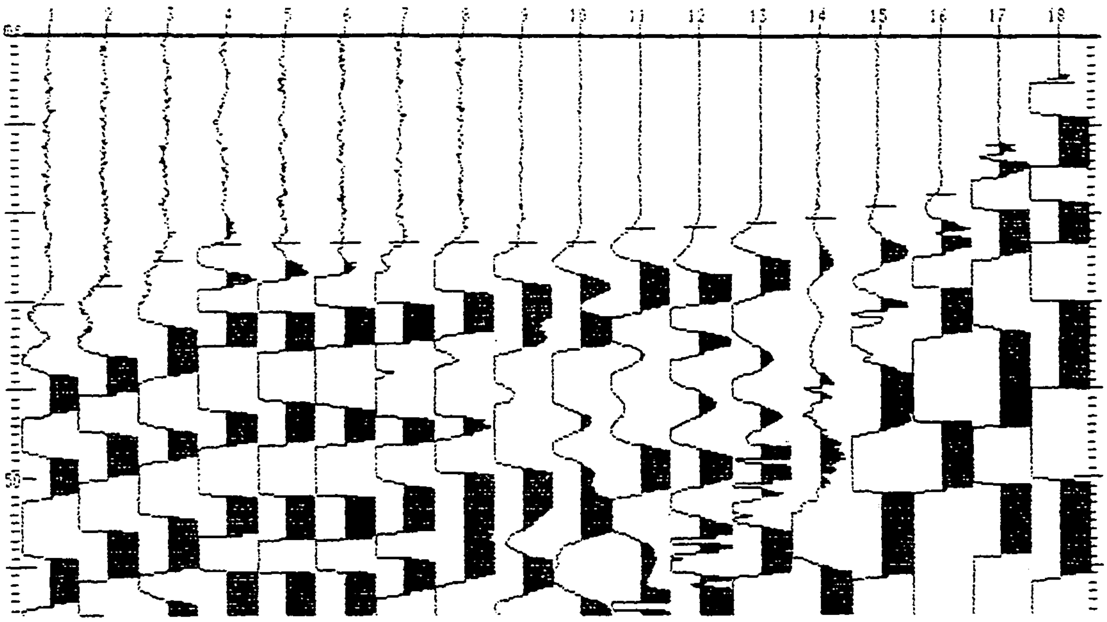
Method: Automatic
Date: 94/02/17
Created: 11:11
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:1



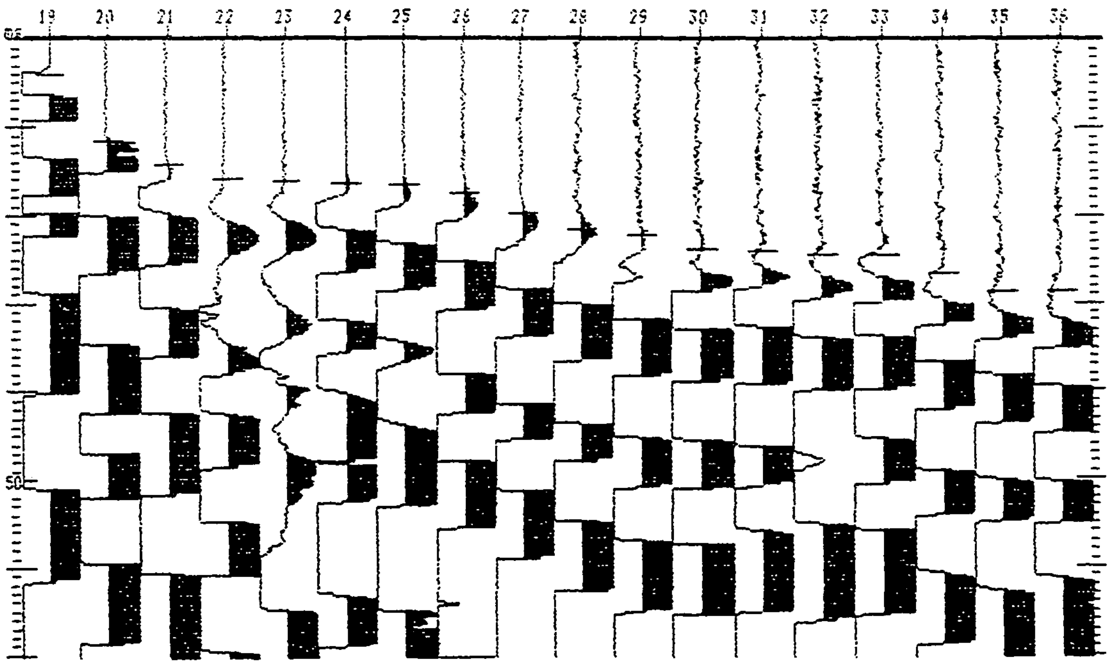
Profile ID: TAMWA4/U3 Method: Automatic
Project: BGS Date: 94/02/17
Customer: ODA Created: 11:11
Cust. ref.: ODA Geoph. spacing: 54.0 m
Operator: JEFF AND PHILI Shot spacing: 3.0 m
Comments: SUNNY WINDY METAL PLATE Start offset: 1.5 m

Channel:2



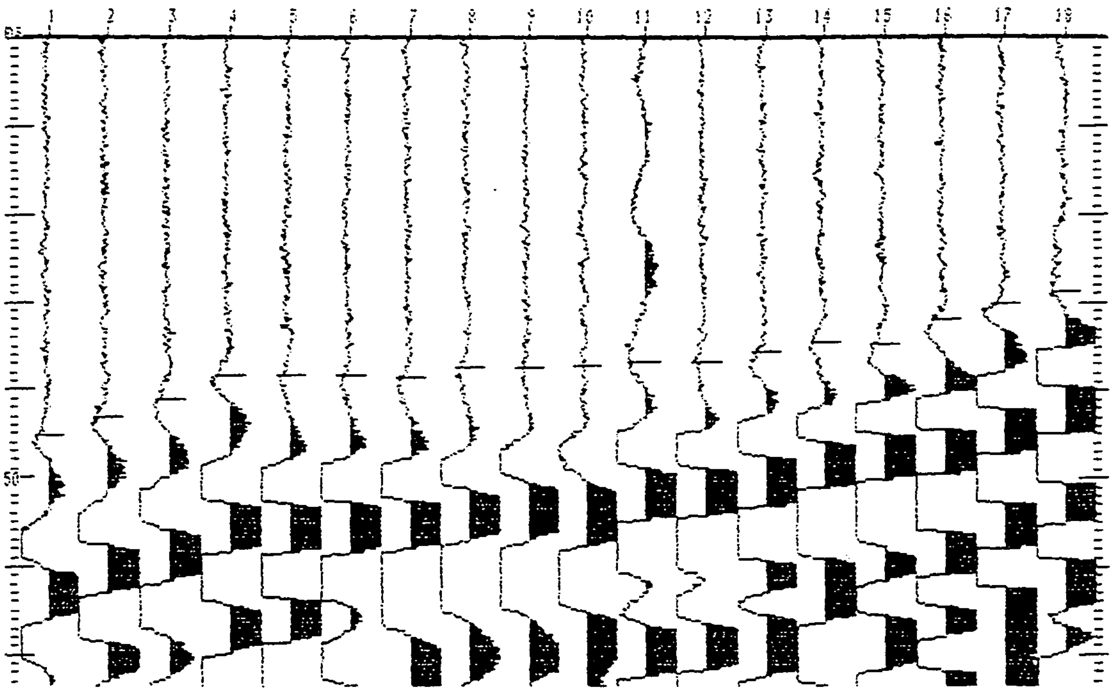
Profile ID: TAMWA4/U3 Method: Automatic
Project: BGS Date: 94/02/17
Customer: ODA Created: 11:11
Cust. ref.: ODA Geoph. spacing: 54.0 m
Operator: JEFF AND PHILI Shot spacing: 3.0 m
Comments: SUNNY WINDY METAL PLATE Start offset: 1.5 m

Channel:2



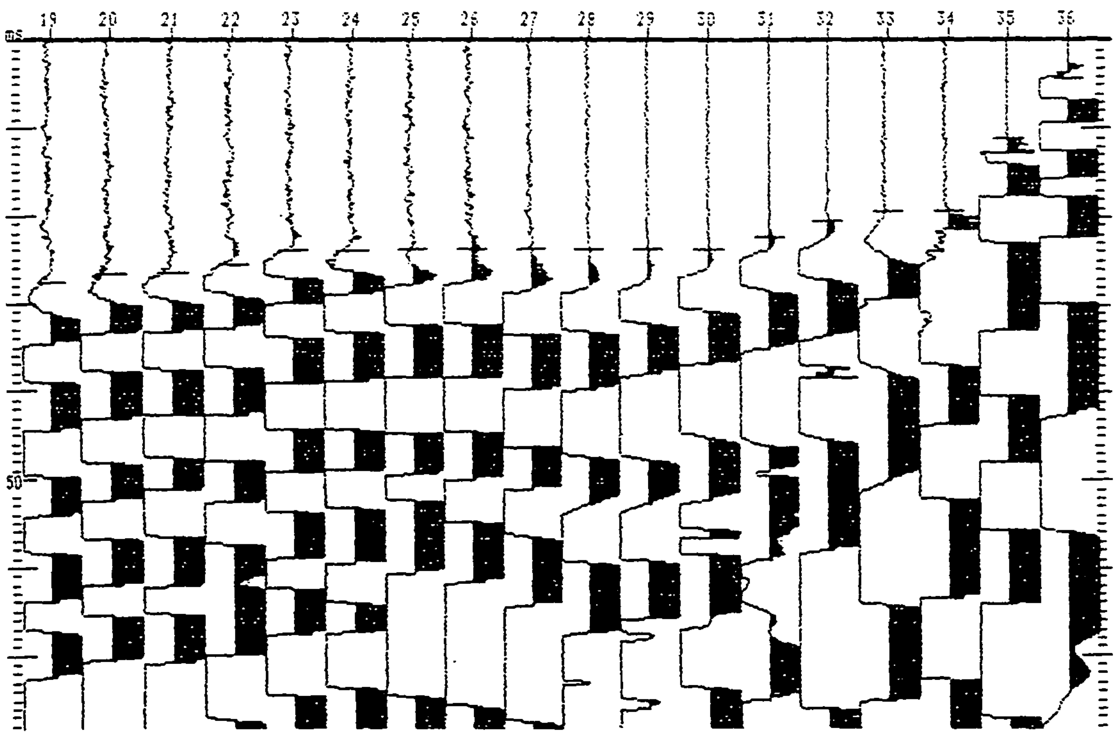
Profile ID:	TAMWA4/U3	Method:	Automatic
Project:	BGS	Date:	94/02/17
Customer:	ODA	Created:	11:11
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILI	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



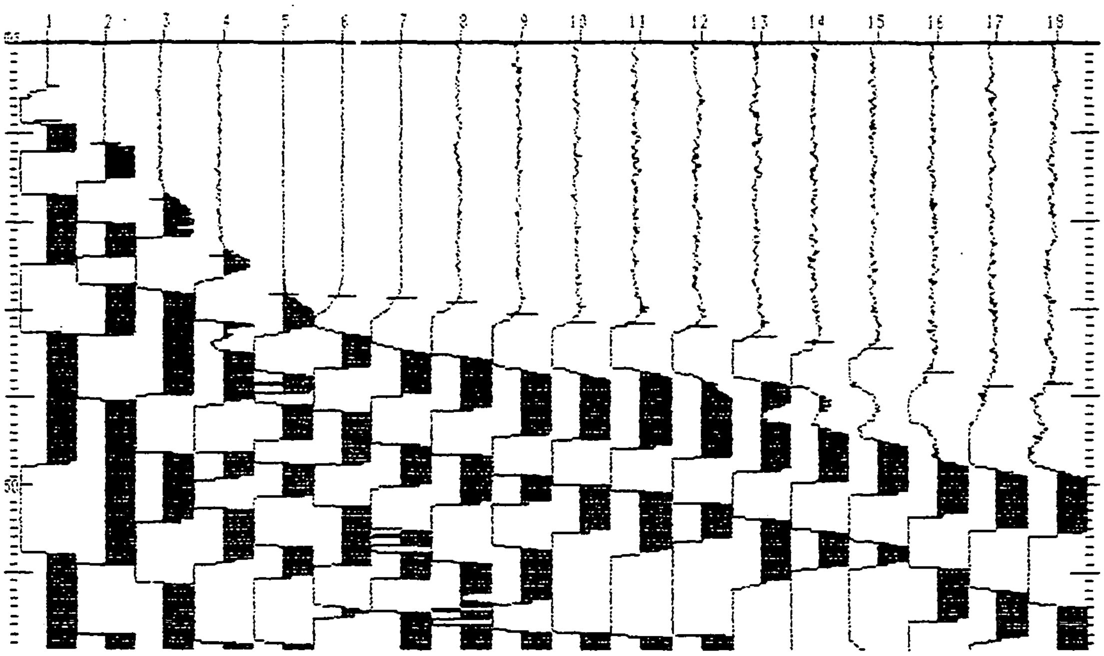
Profile ID:	TAMWA4/U3	Method:	Automatic
Project:	BGS	Date:	94/02/17
Customer:	ODA	Created:	11:11
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILI	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



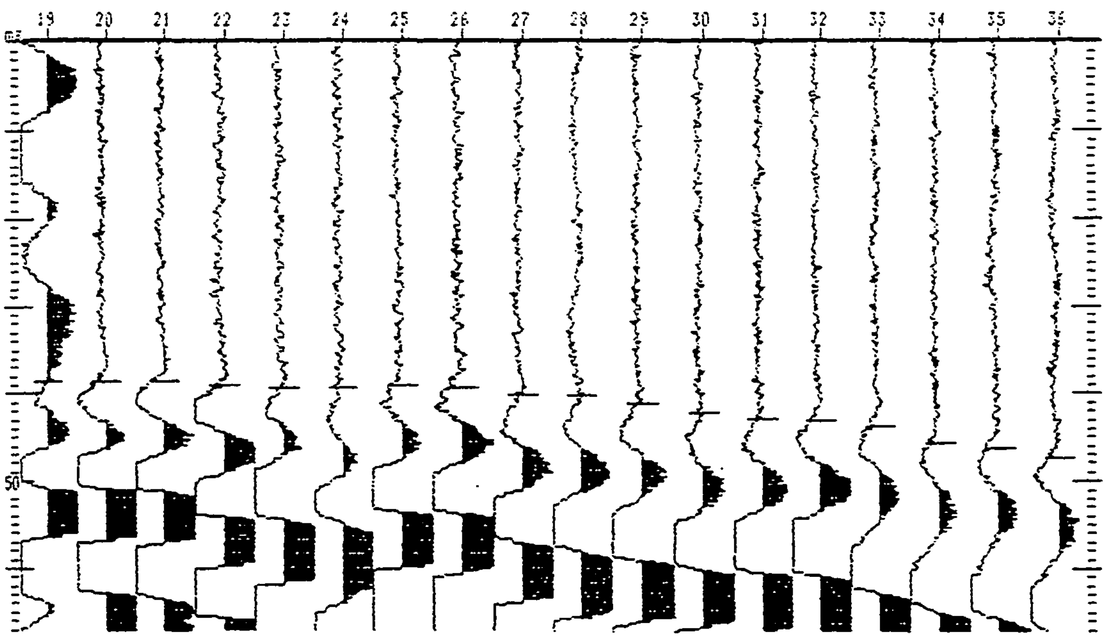
Profile ID:	TAMWA5/U3	Method:	Automatic
Project:	BGS	Date:	94/02/17
Customer:	ODA	Created:	13:57
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILI	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



Profile ID:	TAMWA5/U3	Method:	Automatic
Project:	BGS	Date:	94/02/17
Customer:	ODA	Created:	13:57
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILI	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

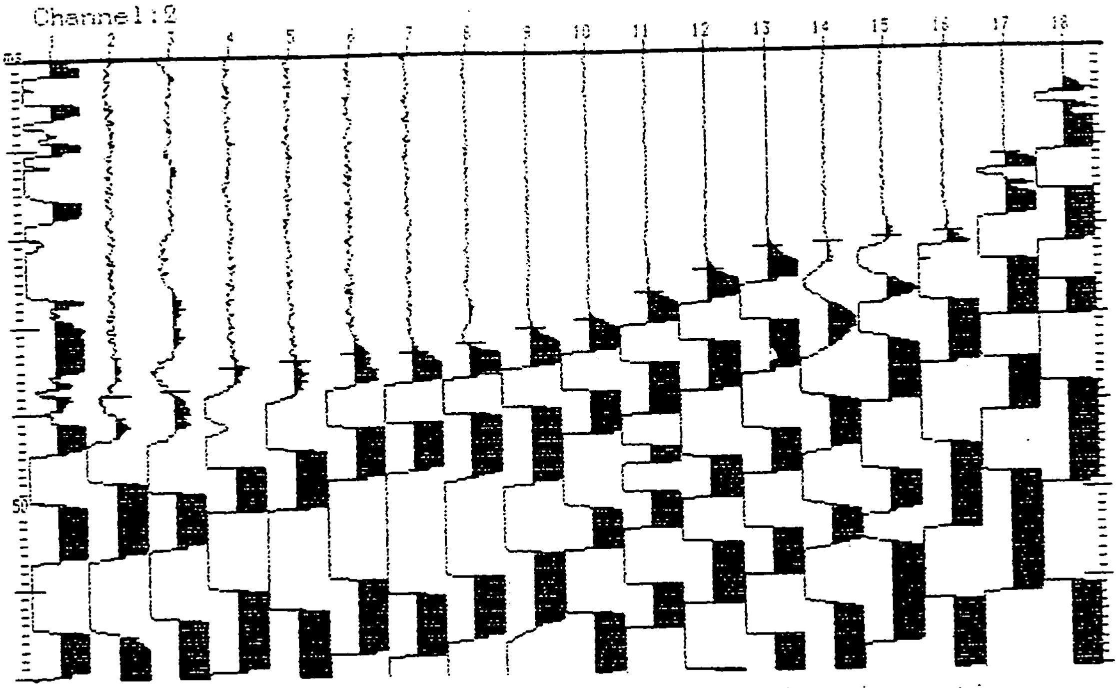
Channel:1



Profile ID: TAMWA5/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/17
Created: 13:57
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

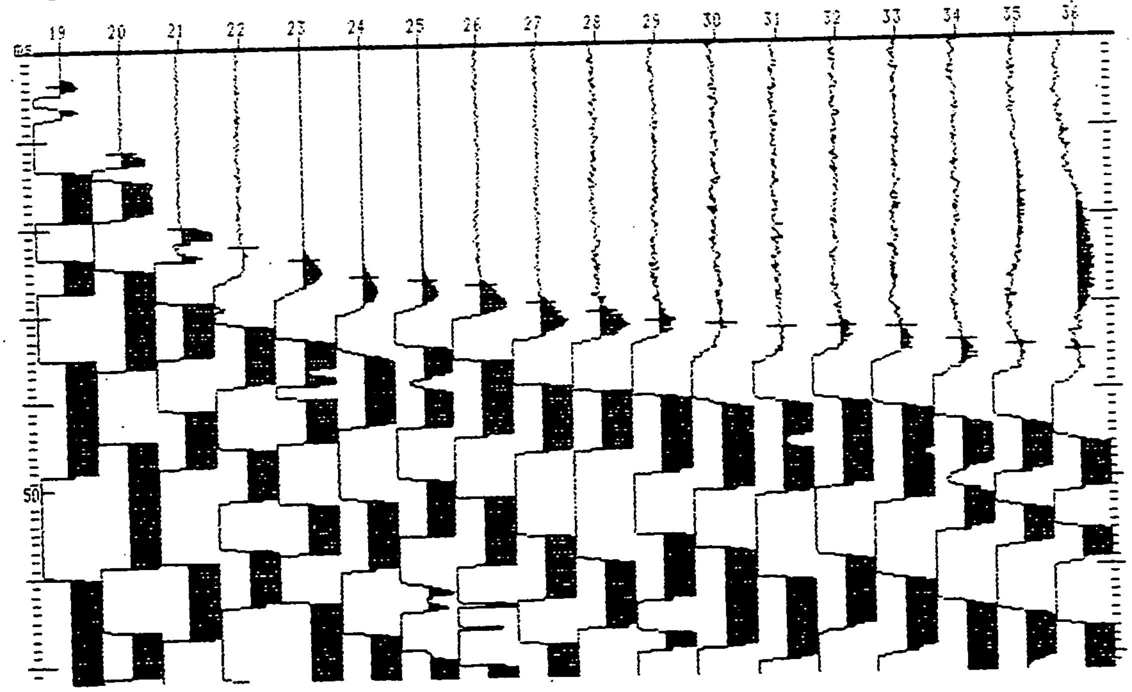
Channel:2



Profile ID: TAMWA5/U3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILI
Comments: SUNNY WINDY METAL PLATE

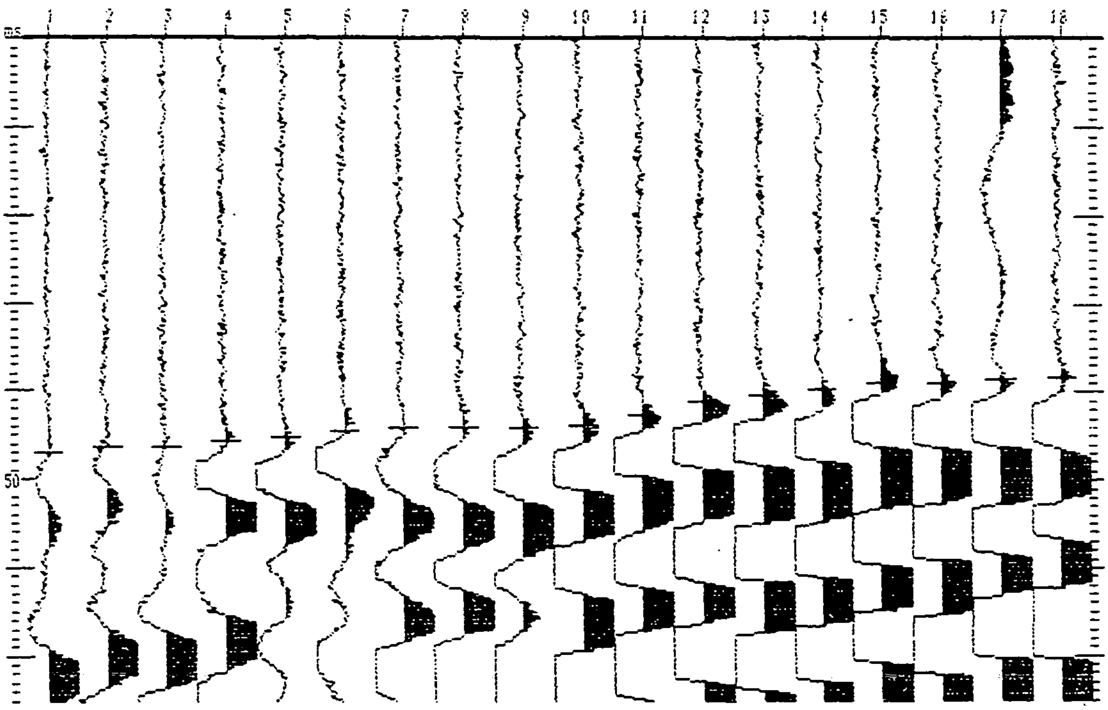
Method: Automatic
Date: 94/02/17
Created: 13:57
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:2



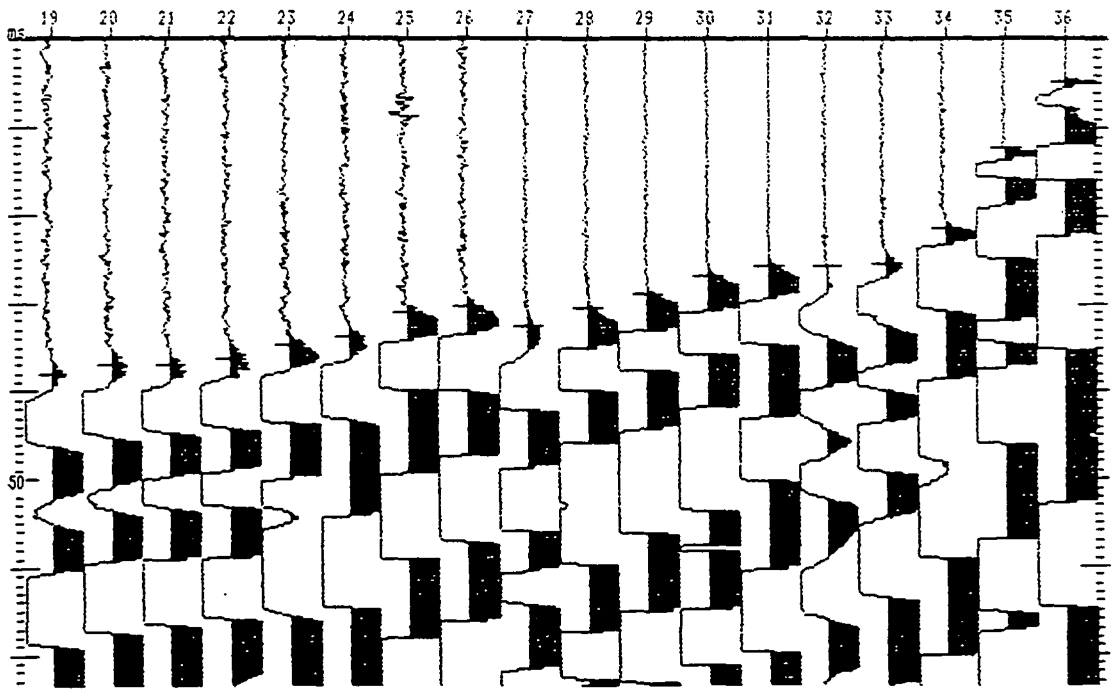
Profile ID:	TAMWA5/U3	Method:	Automatic
Project:	BGS	Date:	94/02/17
Customer:	ODA	Created:	13:57
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILI	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



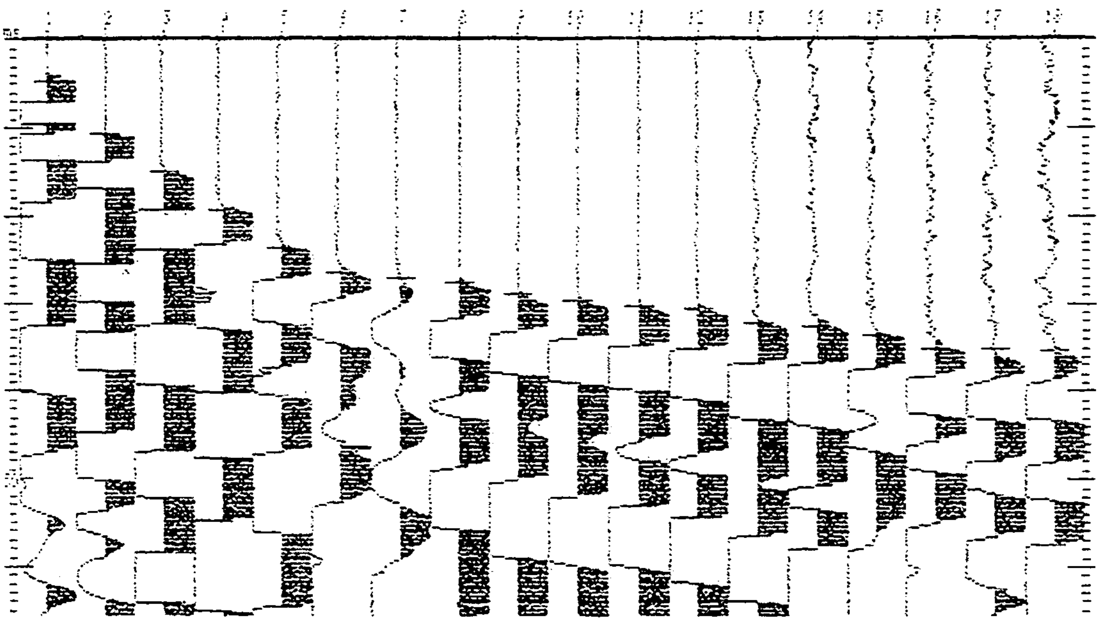
Profile ID:	TAMWA5/U3	Method:	Automatic
Project:	BGS	Date:	94/02/17
Customer:	ODA	Created:	13:57
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILI	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



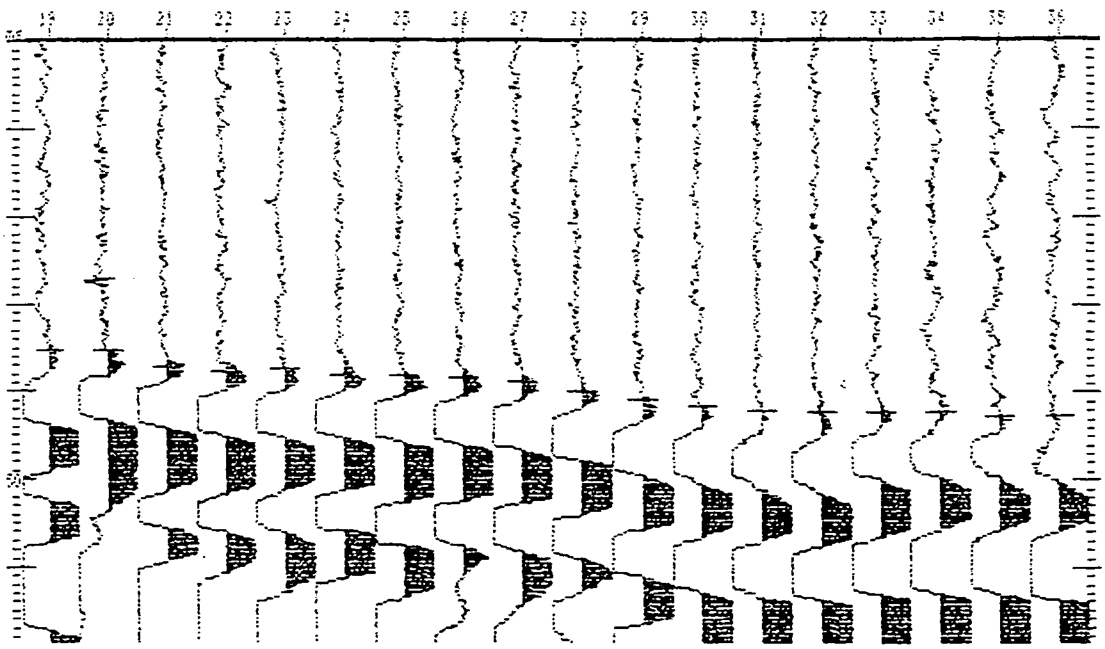
Profile ID: TAMWA8/01 Method: Automatic
Project: BGS Date: 94/02/18
Customer: ODA Created: 09:12
Cust. ref.: ODA Geoph. spacing: 54.0 m
Operator: JEFF AND PHILL Shot spacing: 3.0 m
Comments: SUNNY WINDY METAL PLATE Start offset: 1.5 m

Channel:1

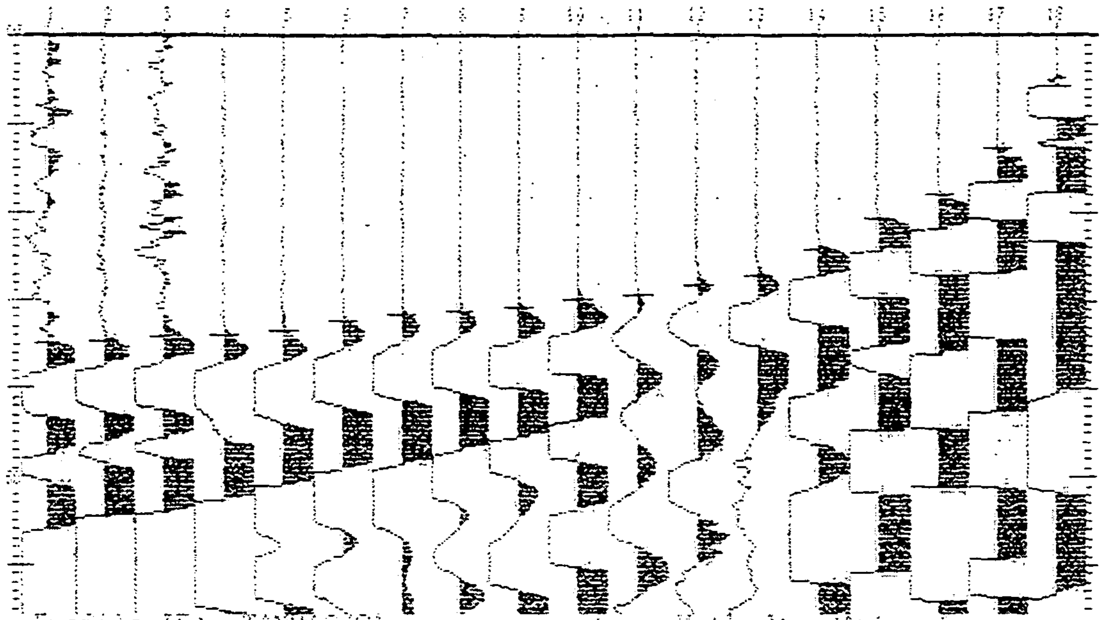


Profile ID: TAMWA8/01 Method: Automatic
Project: BGS Date: 94/02/18
Customer: ODA Created: 09:12
Cust. ref.: ODA Geoph. spacing: 54.0 m
Operator: JEFF AND PHILL Shot spacing: 3.0 m
Comments: SUNNY WINDY METAL PLATE Start offset: 1.5 m

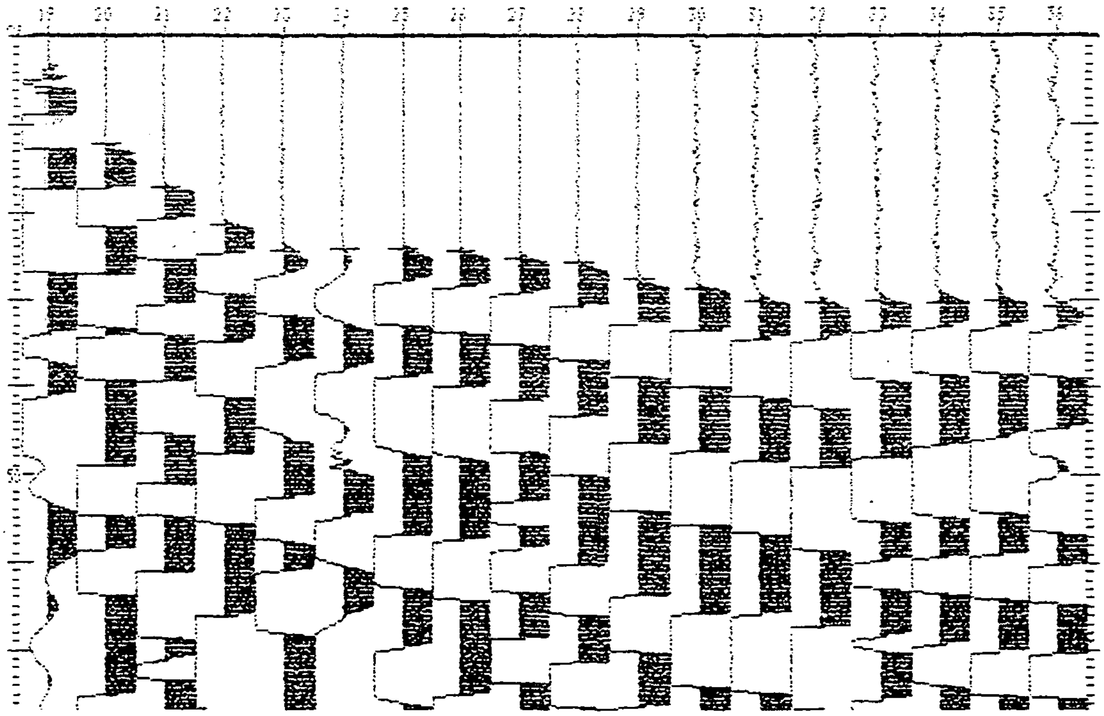
Channel:1



Profile ID: [illegible]
Comments: SUNNY WINDY METAL PLATE
Method: [illegible]
Step spacing: 54.0 m
Start offset: 1.5 m
Channel:2

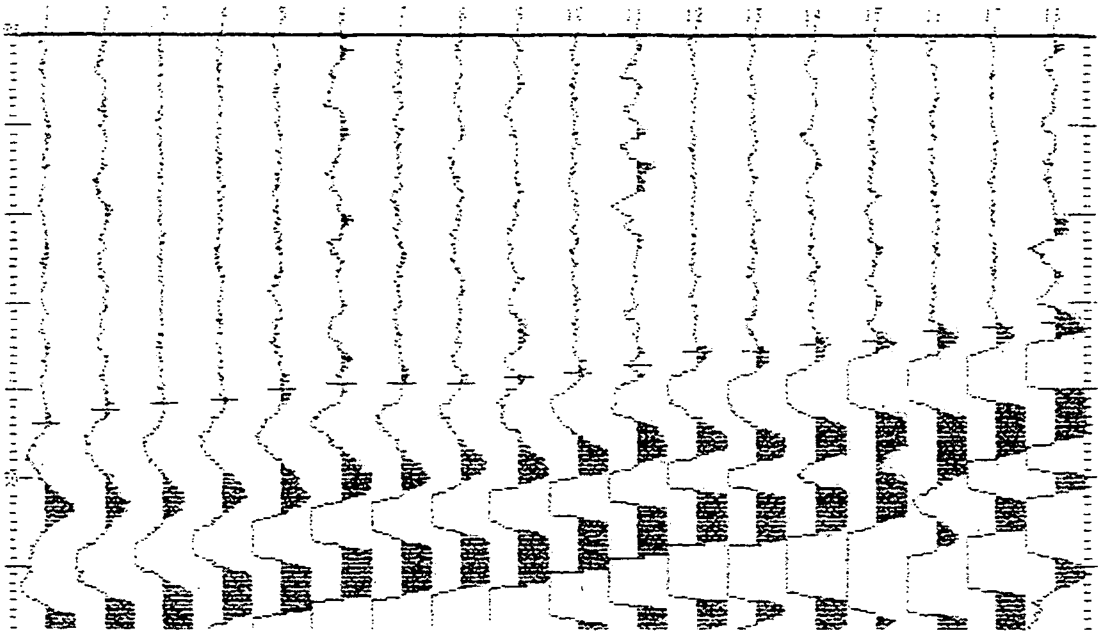


Profile ID: [illegible]
Operator: [illegible] AND [illegible]
Comments: SUNNY WINDY METAL PLATE
Method: Automatic
Step spacing: 54.0 m
Start offset: 1.5 m
Channel:2



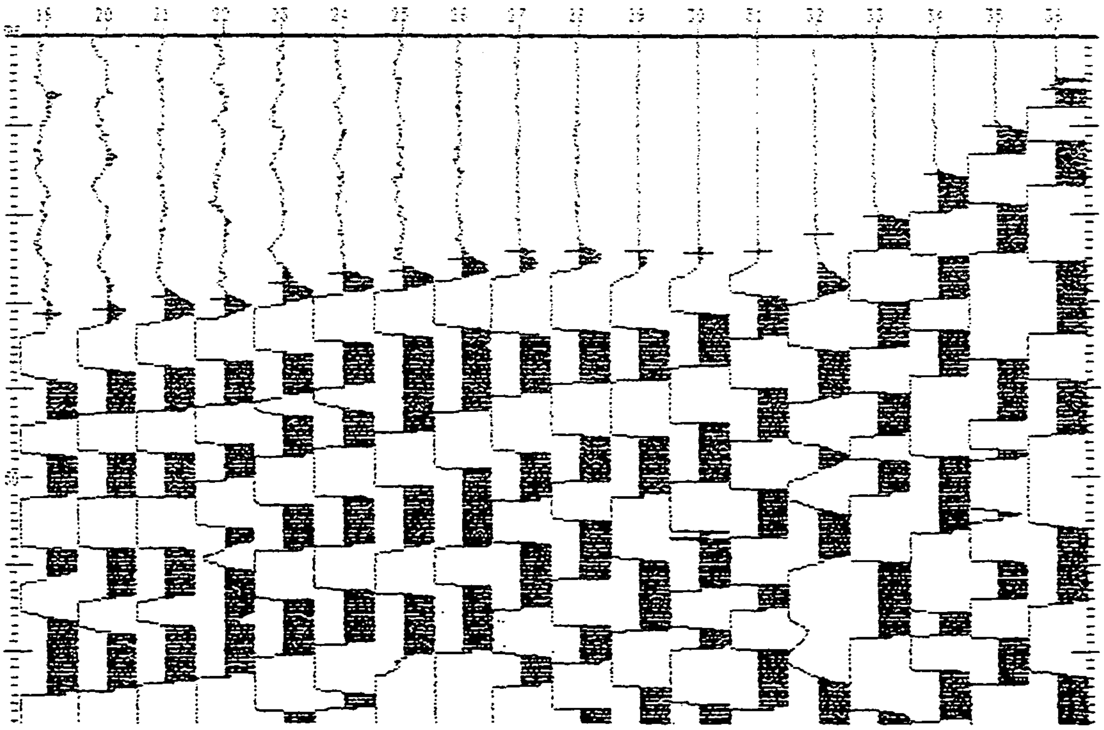
Profile ID:	[illegible]	Method:	[illegible]
Project:	[illegible]	Date:	[illegible]
Customer:	[illegible]	Created:	[illegible]
Cust. ref.:	[illegible]	Geoph. spacing:	[illegible]
Operator:	JEFF AND PHILL	Shot spacing:	[illegible]
Comments:	[illegible]	Start offset:	[illegible]

Channel:[illegible]



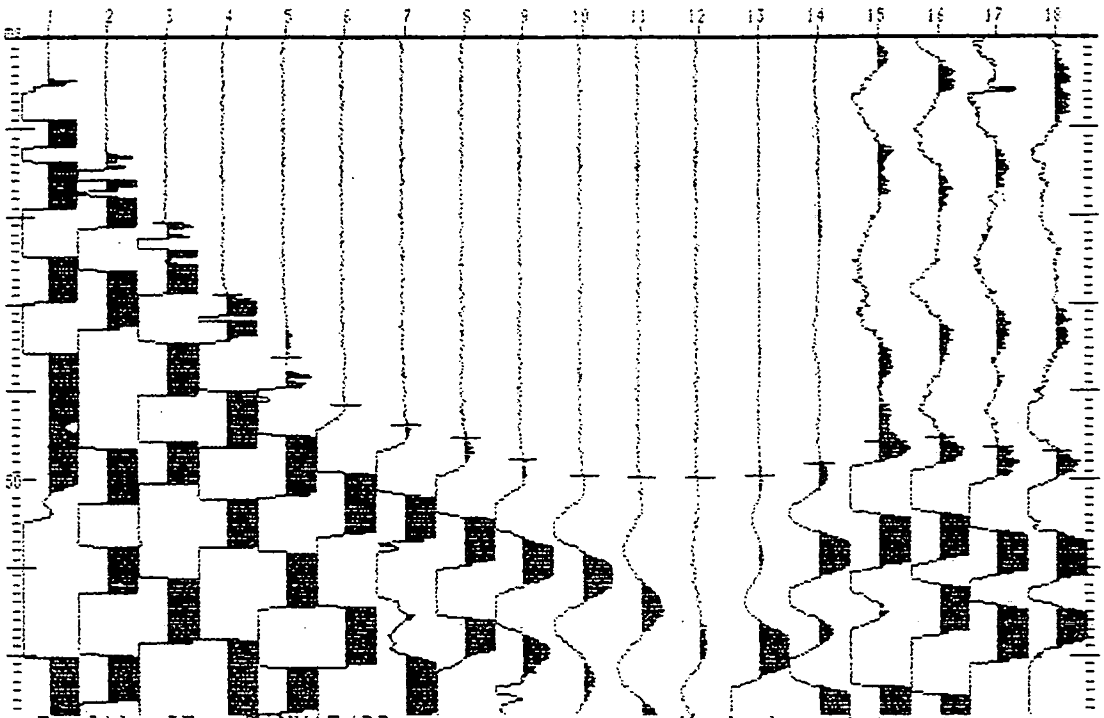
Profile ID:	TAMWA8/Q1	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	09:12
Cust. ref :	ODA	Geoph. spacing:	[illegible] m
Operator:	JEFF AND PHILL	Shot spacing:	[illegible] m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	[illegible] m

Channel:3



Profile ID:	TAMWA7/Q2	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	11:23
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

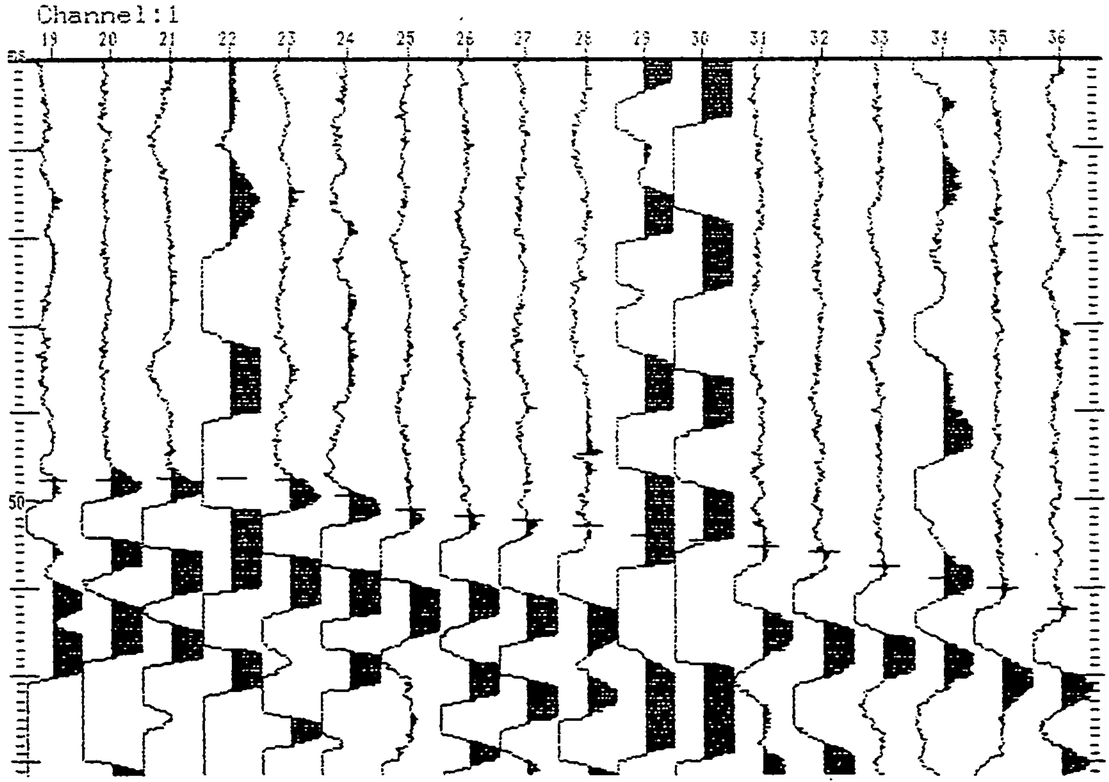
Channel:1



2

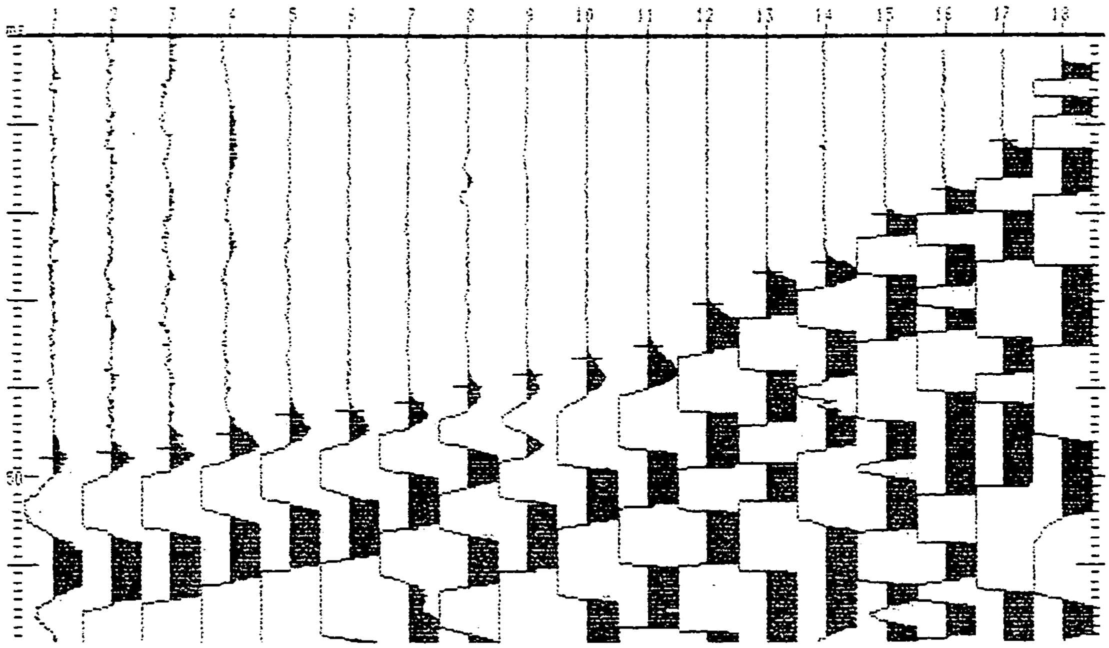
Profile ID: TAMWA7/Q2 Method: Automatic
Operator: JEFF AND PHILL
Comments: SUNNY WINDY METAL PLATE
54.0 m

Channel:1



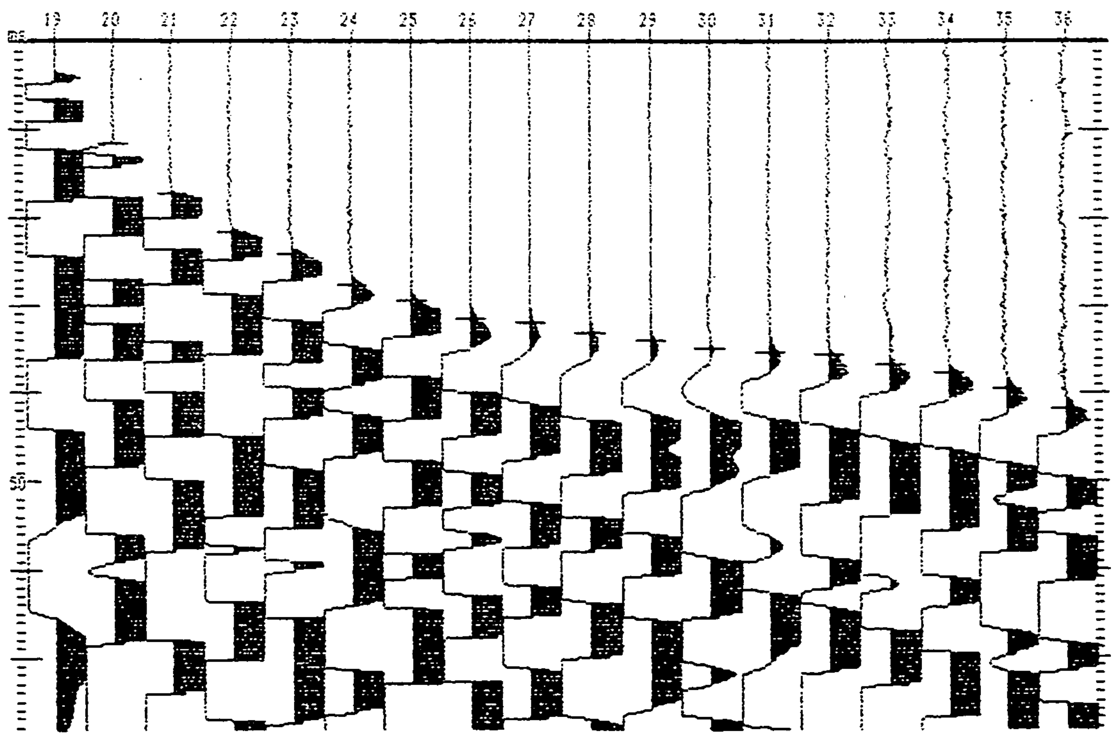
Profile ID:	TAMWA7/Q2	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	11:23
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:2



Profile ID:	TAMWA7/Q2	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	11:23
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

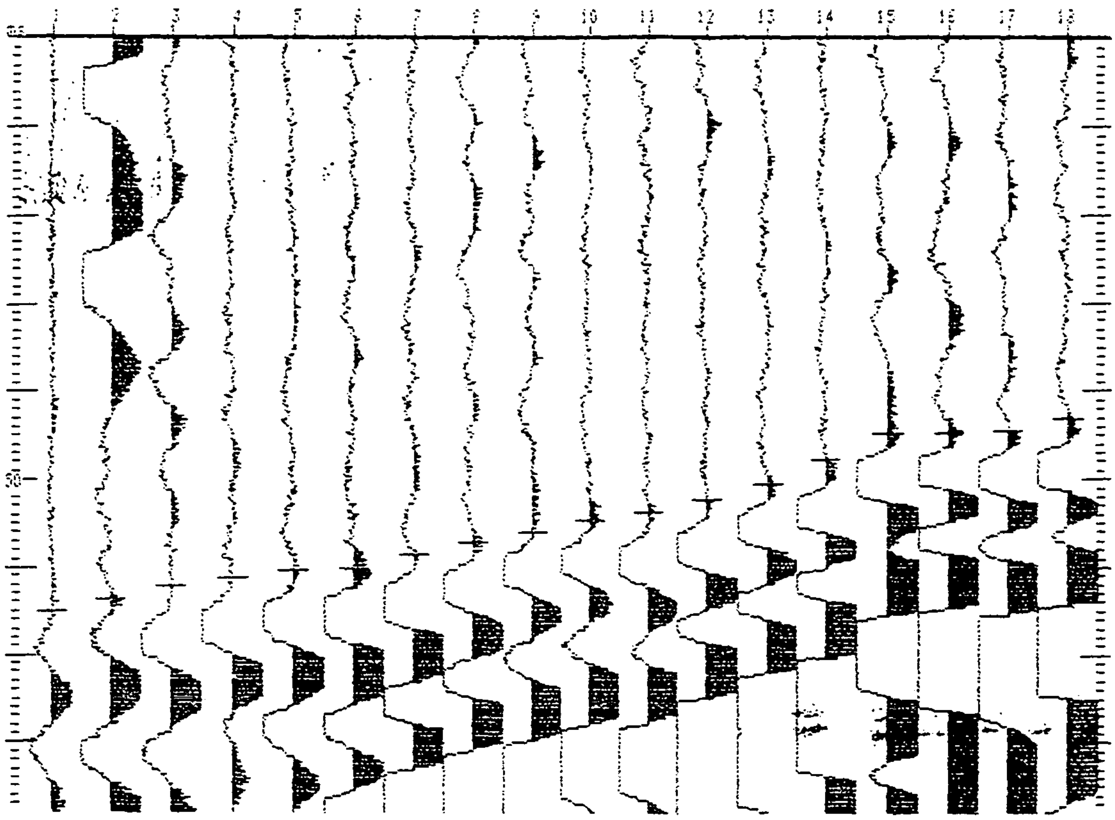
Channel:2



Profile ID: TAMWA7/Q2
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/18
Created: 11:23
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

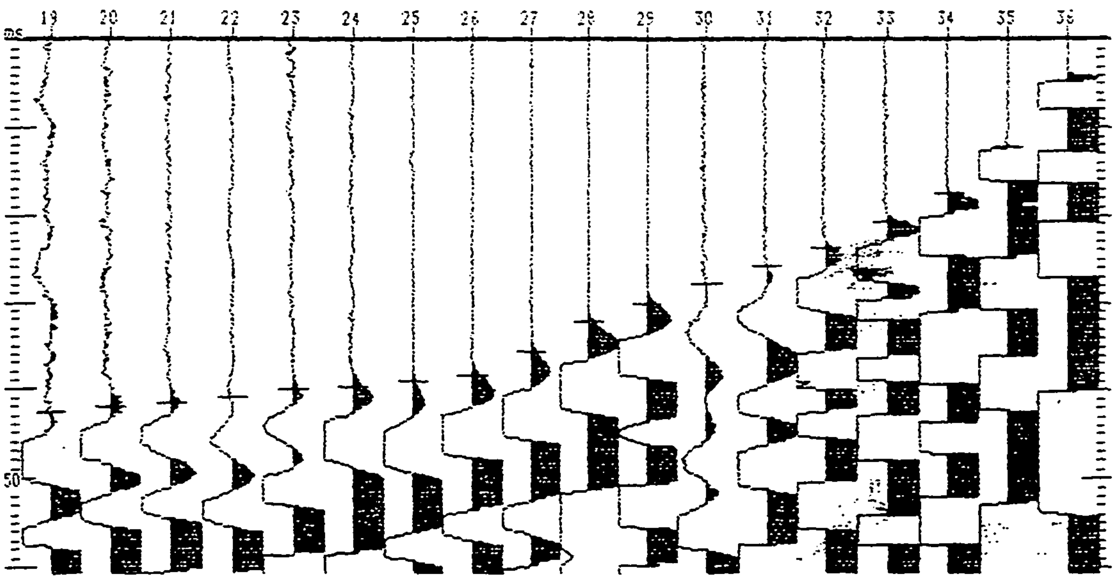
Channel:3



Profile ID: TAMWA7/Q2
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/18
Created: 11:23
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

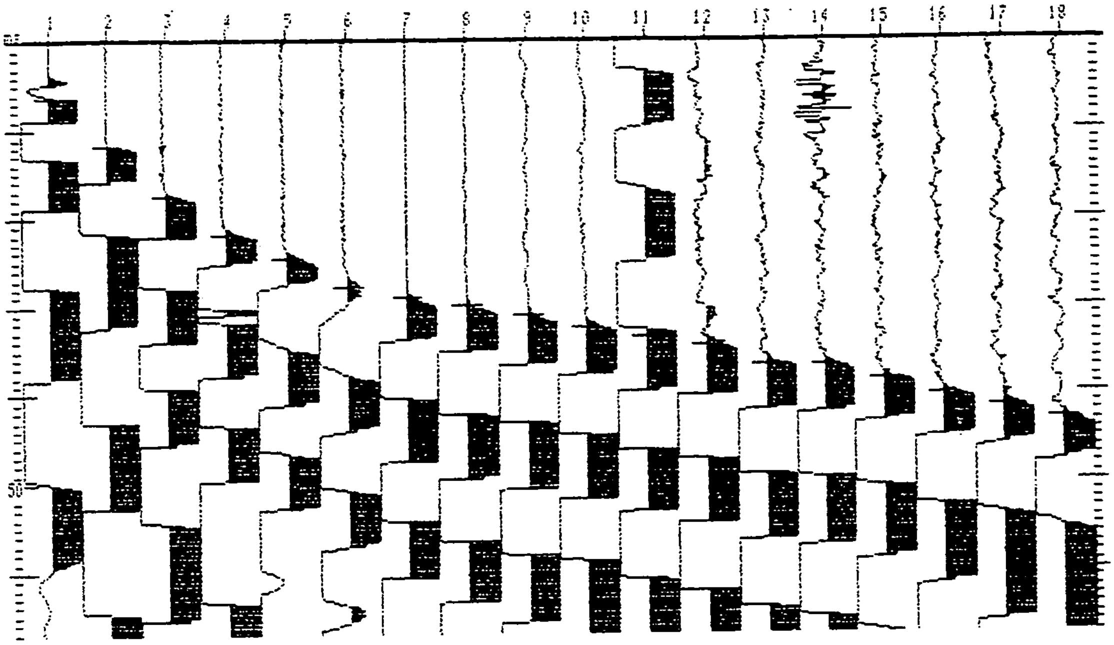
Channel:3



Profile ID: TAMWA8/Q3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: SUNNY WINDY METAL PLATE

Method: Automatic
Date: 94/02/18
Created: 13:51
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

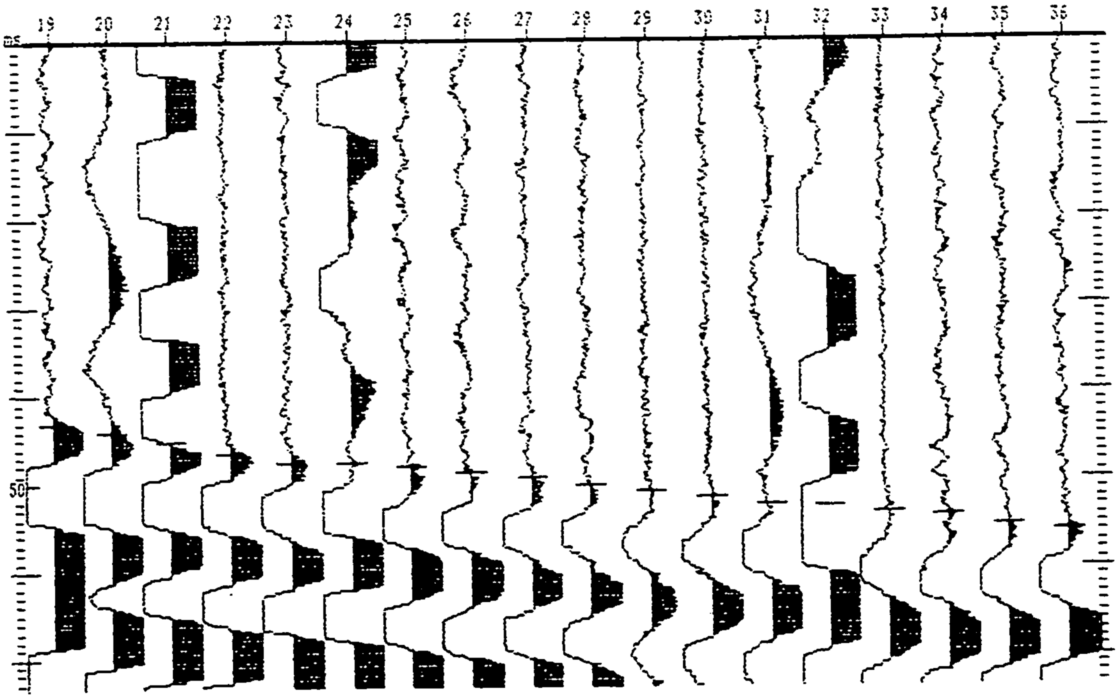
Channel:1



Profile ID: TAMWA8/Q3
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: SUNNY WINDY METAL PLATE

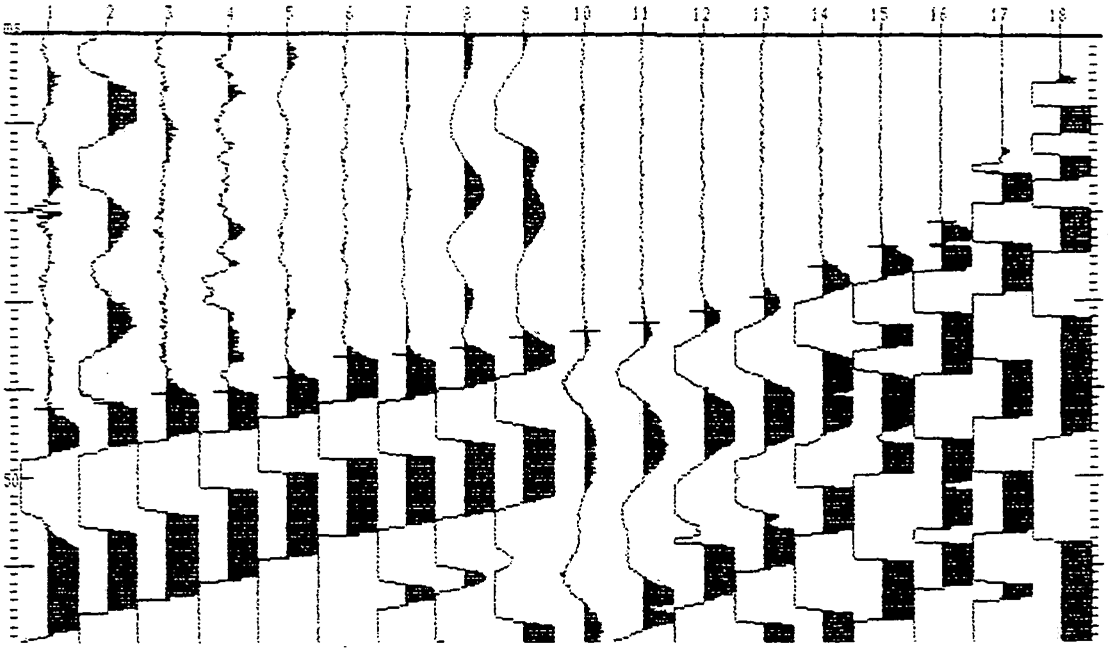
Method: Automatic
Date: 94/02/18
Created: 13:51
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:1



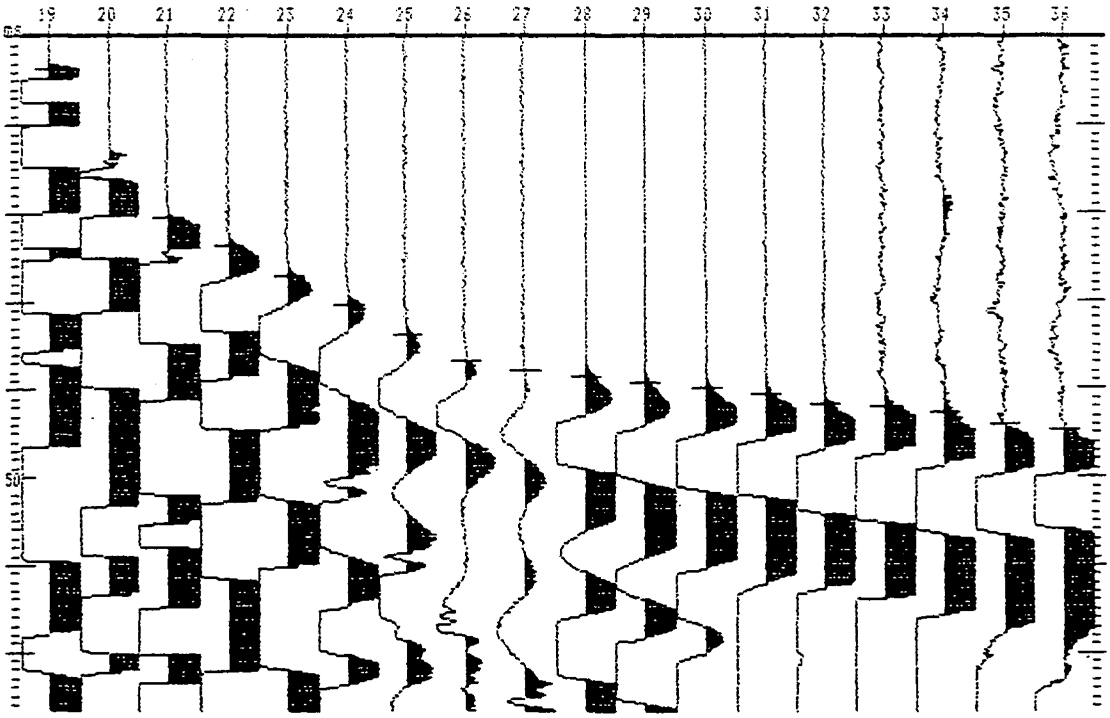
Profile ID:	TAMWA8/Q3	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	13:51
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:2



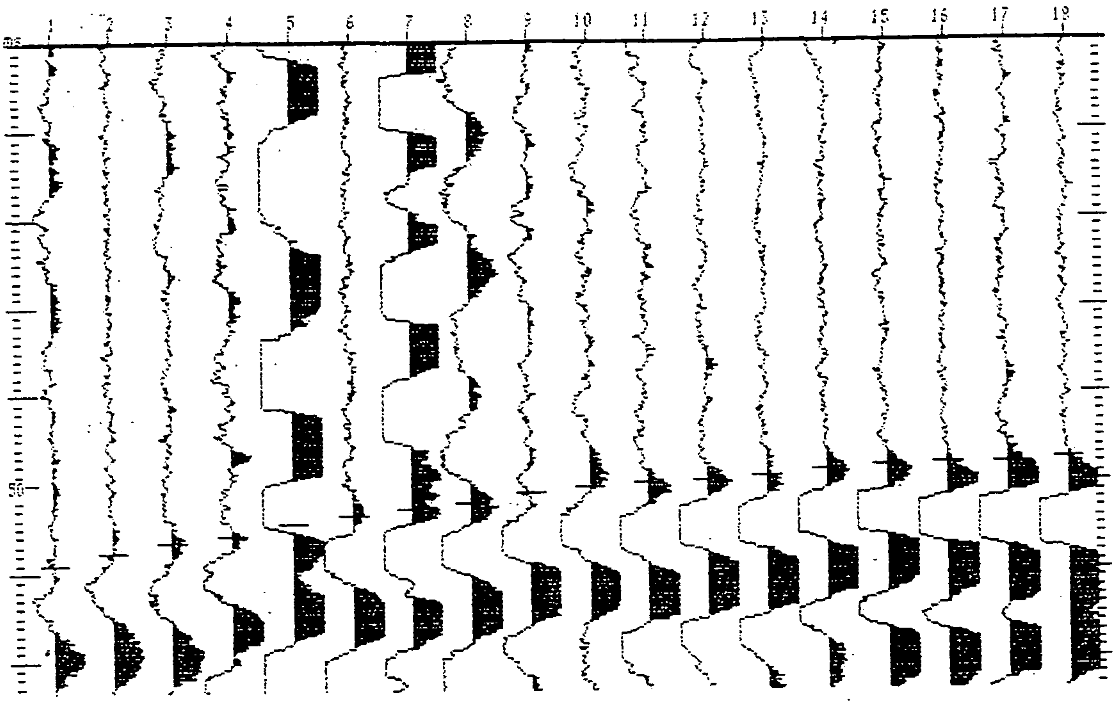
Profile ID:	TAMWA8/Q3	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	13:51
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:2



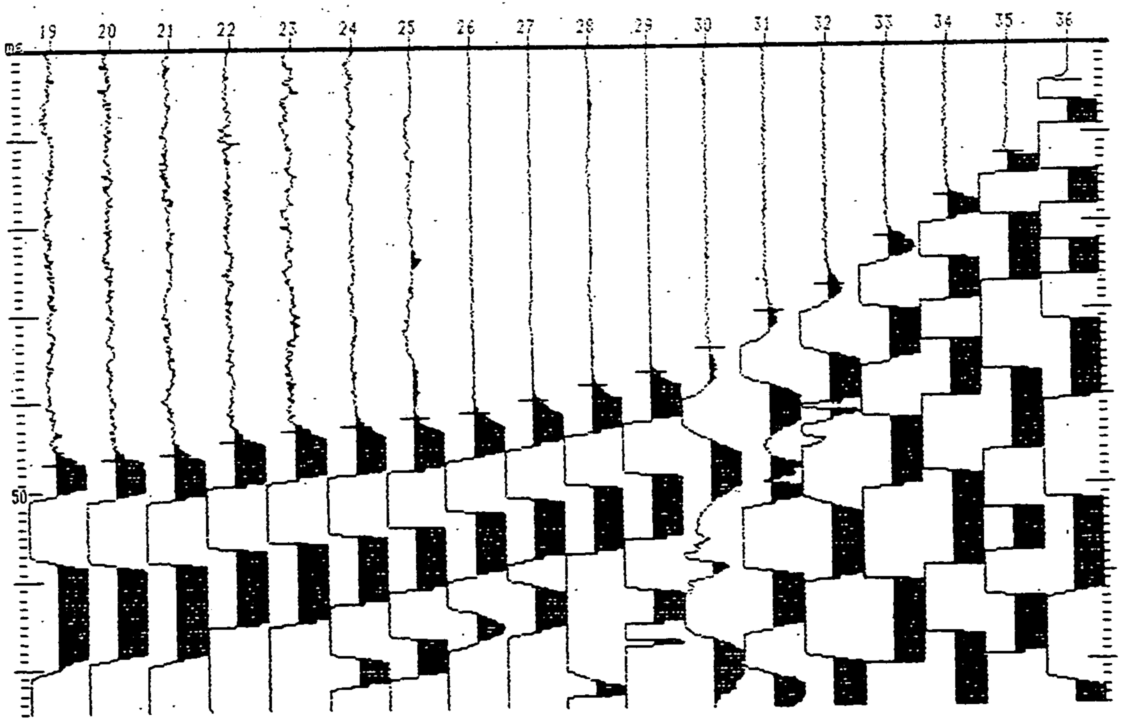
Profile ID:	TAMWA8/Q3	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	13:51
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



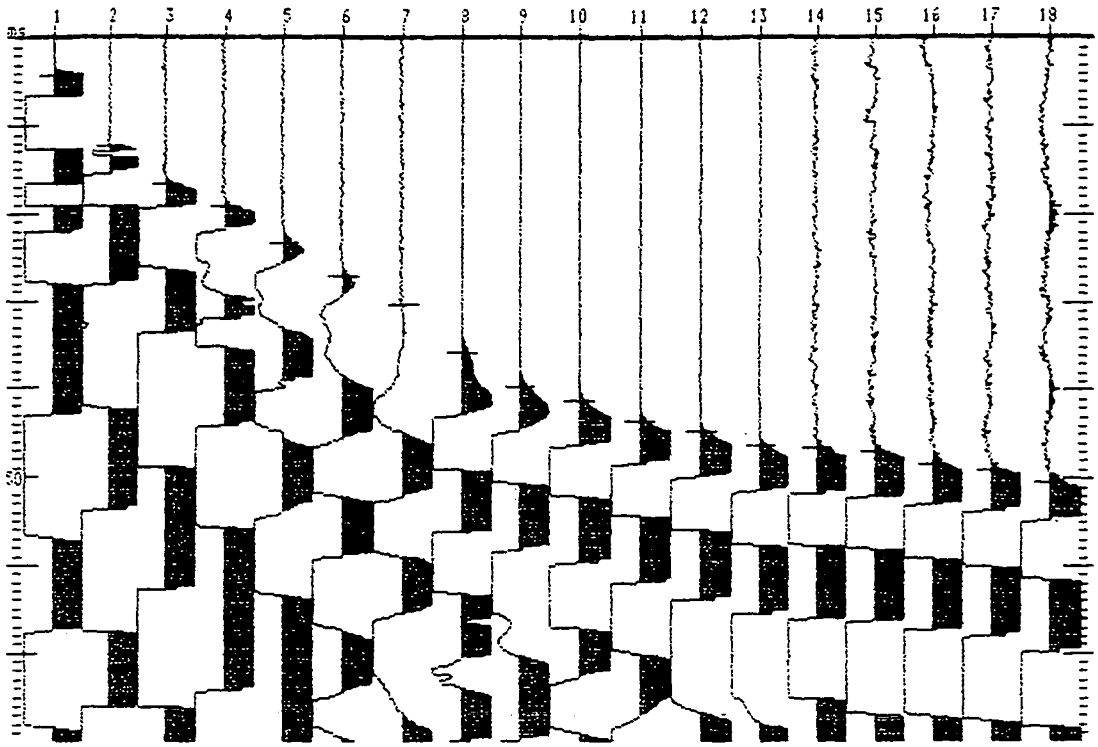
Profile ID:	TAMWA8/Q3	Method:	Automatic
Project:	BGS	Date:	94/02/18
Customer:	ODA	Created:	13:51
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	SUNNY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



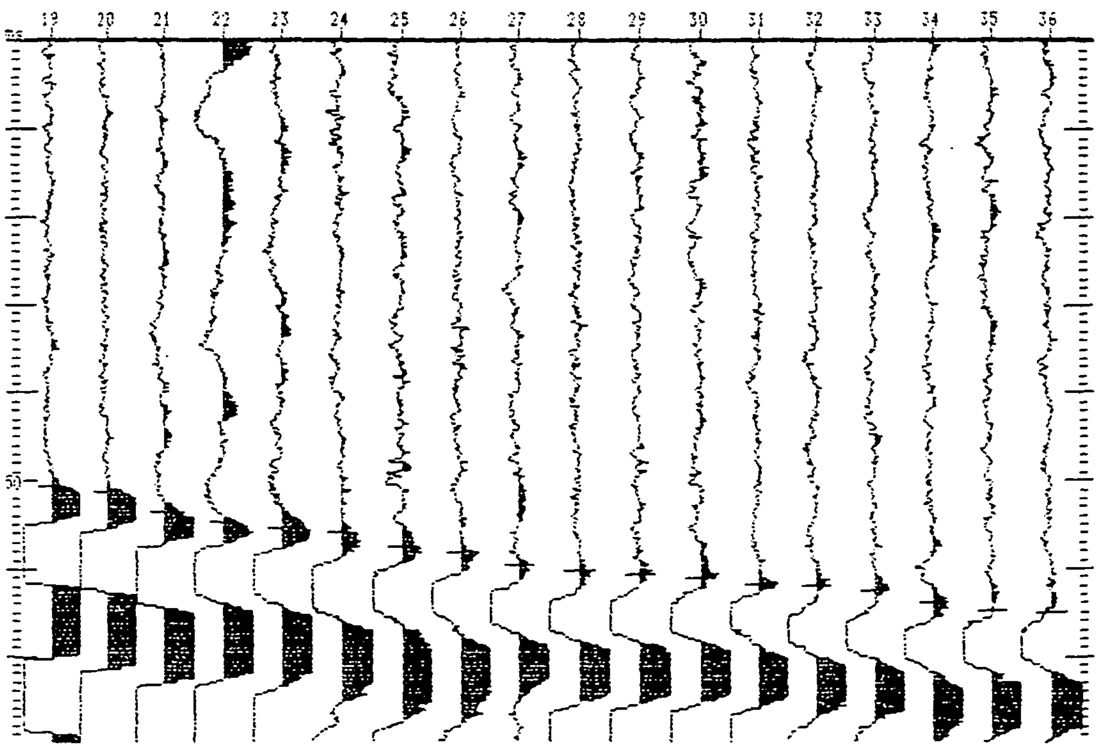
Profile ID:	TAMWA9/K4	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	09:37
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



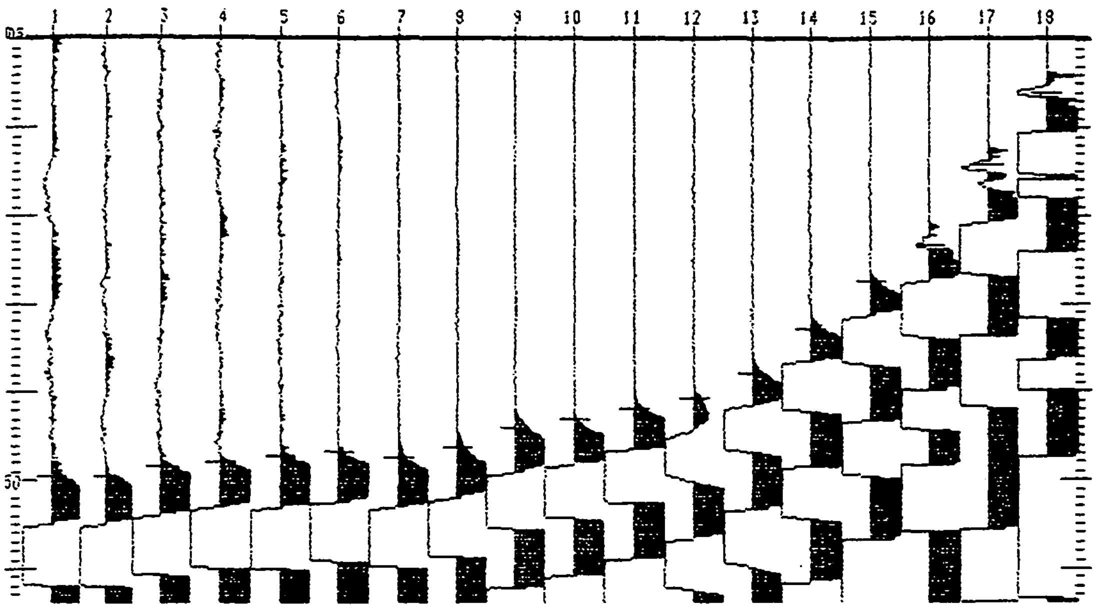
Profile ID:	TAMWA9/K4	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	09:37
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



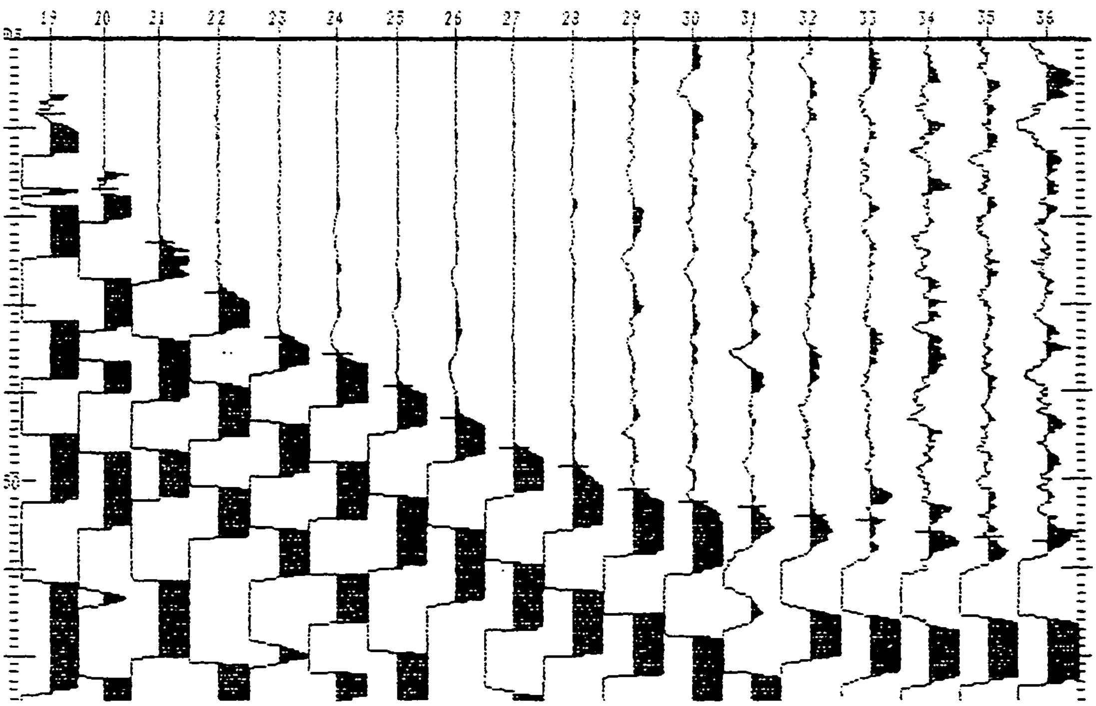
Profile ID:	TAMWA9/K4	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	09:37
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:2



Profile ID:	TAMWA9/K4	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	09:37
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

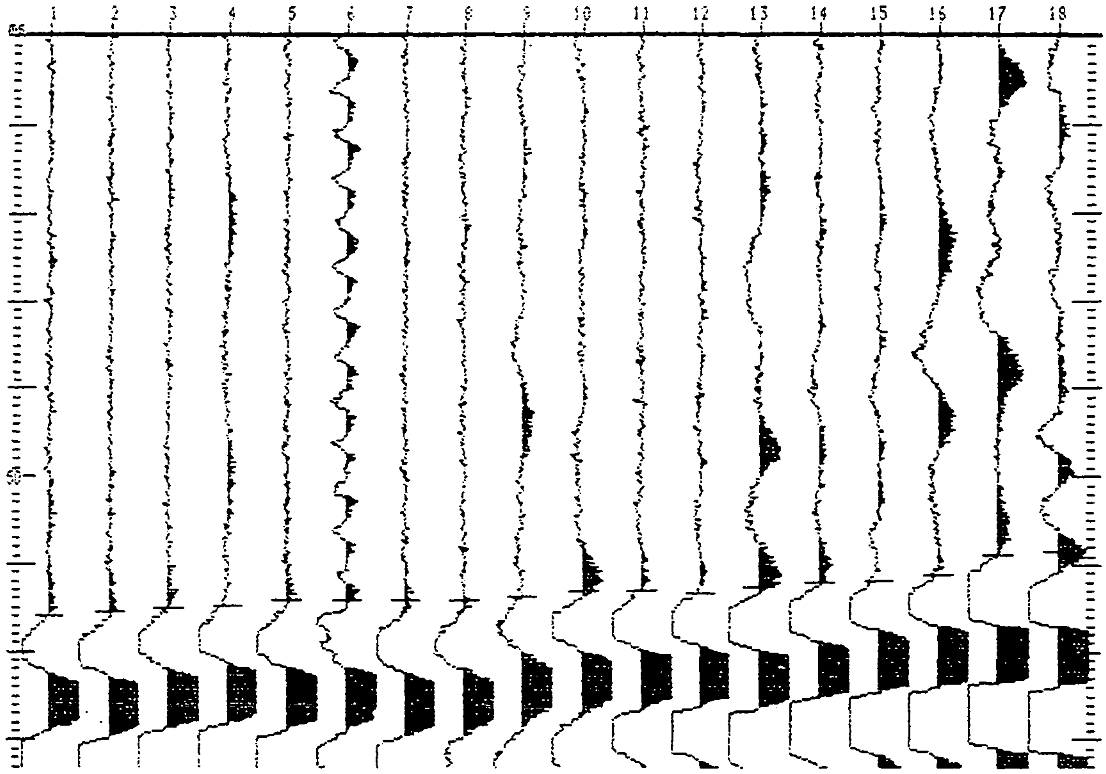
Channel:2



Profile ID: TAMWA9/K4
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/21
Created: 09:37
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

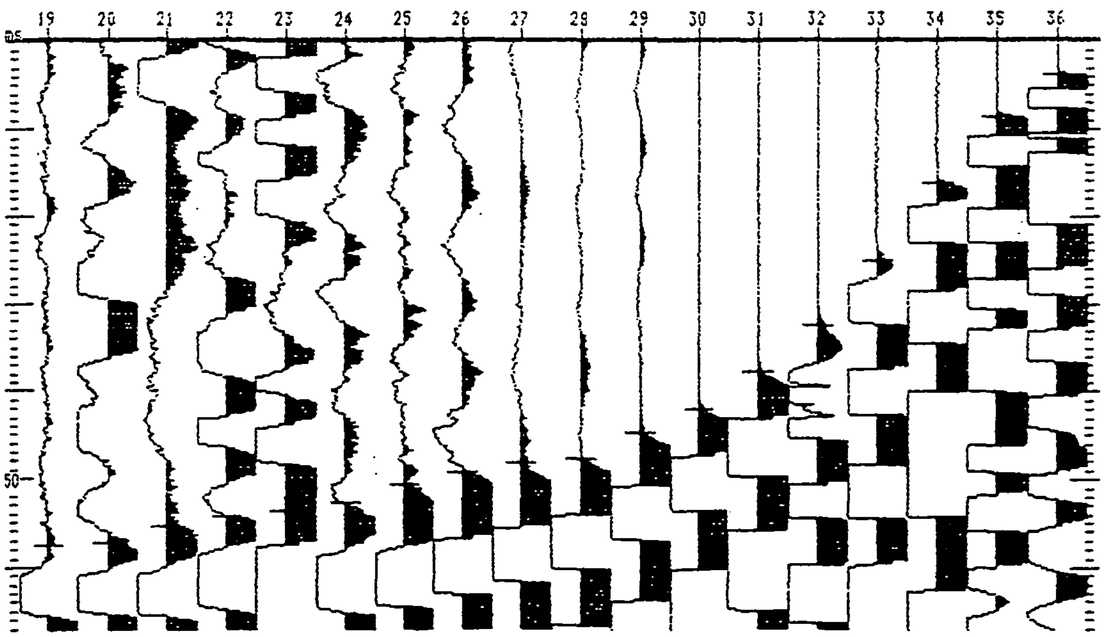
Channel:3



Profile ID: TAMWA9/K4
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/21
Created: 09:37
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

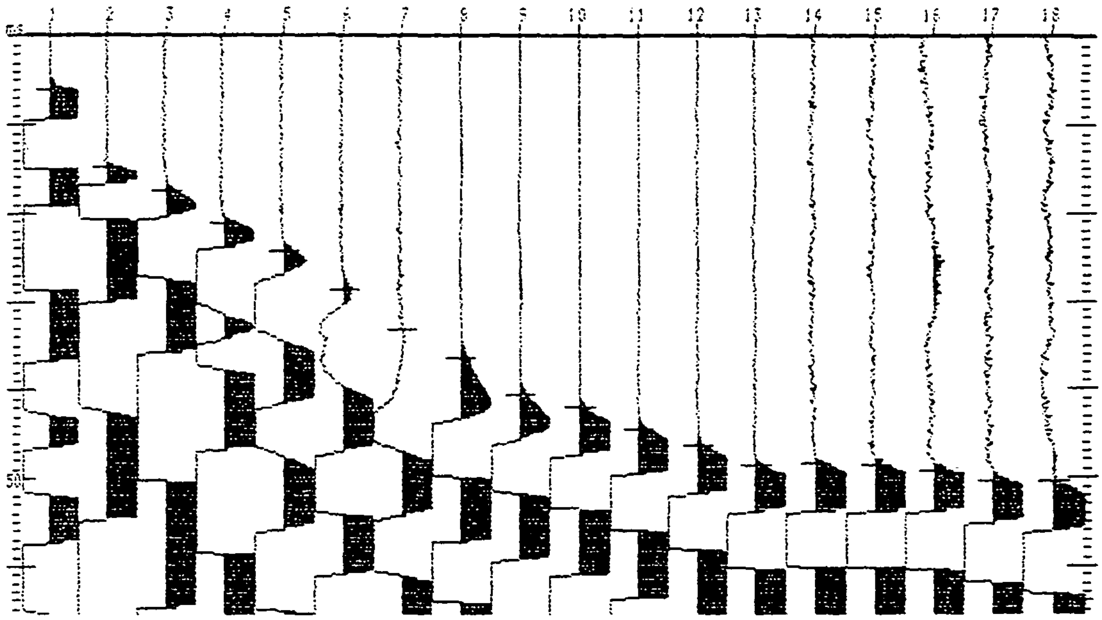
Channel:3



Profile ID: TAMWA10/K4/R
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY CAALM RESIN PLATE

Method: Automatic
Date: 94/02/21
Created: 13:04
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

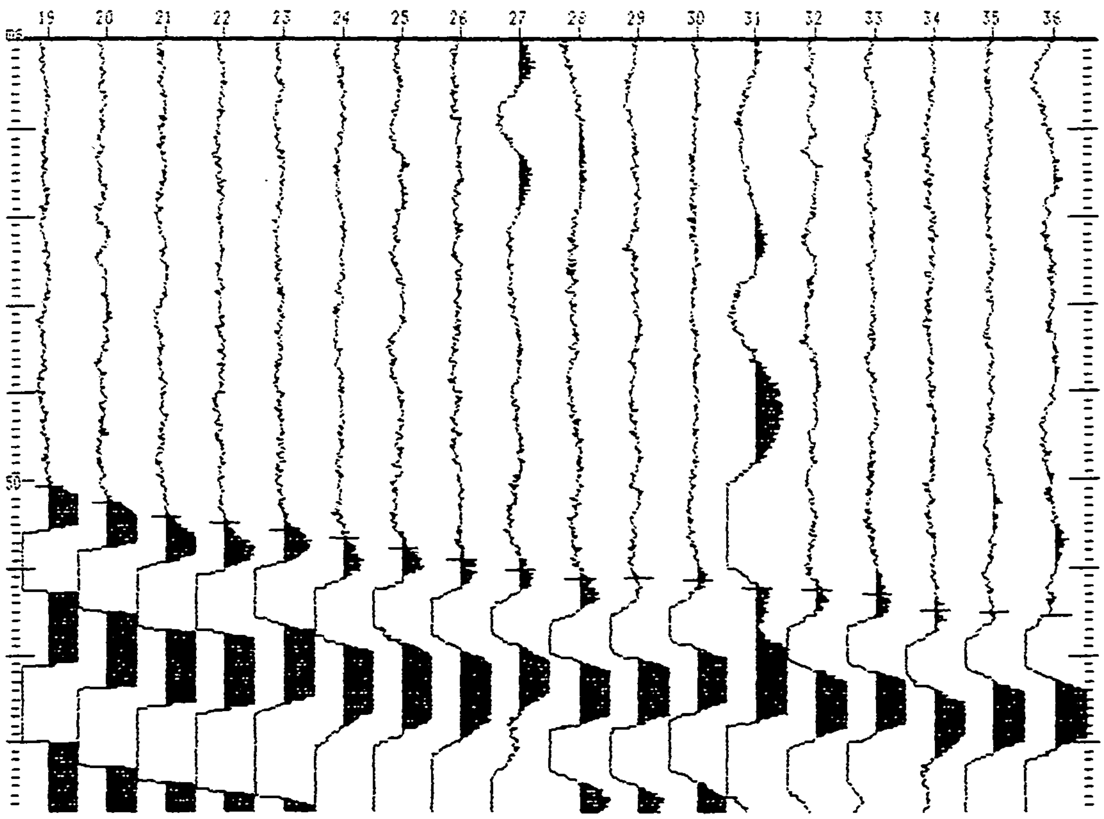
Channel:1



Profile ID: TAMWA10/K4/R
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY CAALM RESIN PLATE

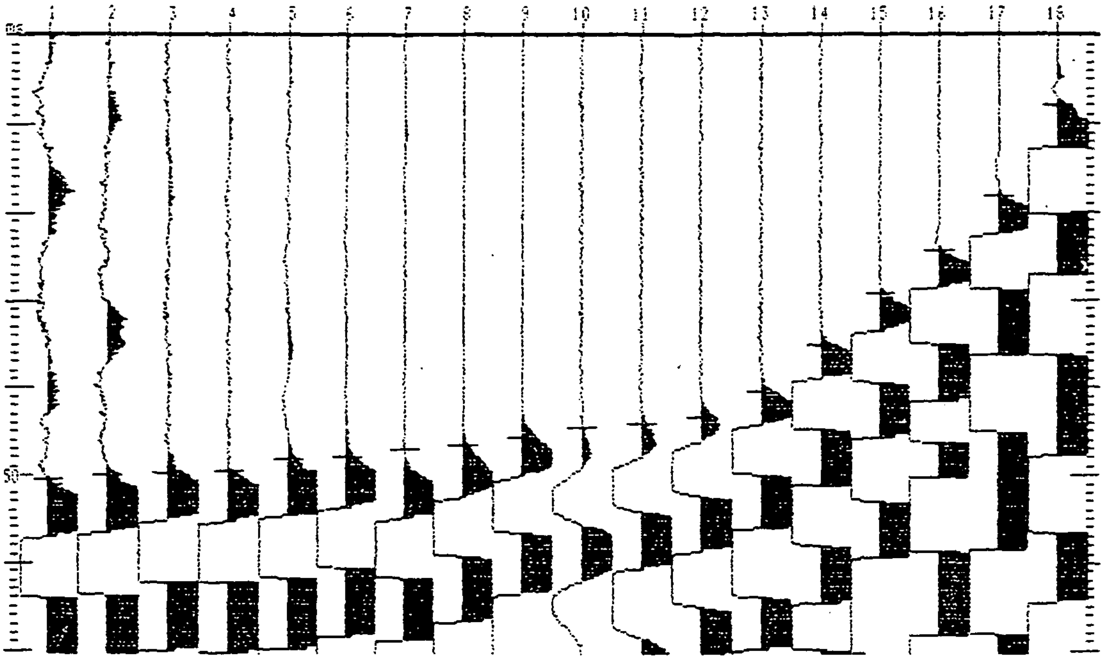
Method: Automatic
Date: 94/02/21
Created: 13:04
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:1



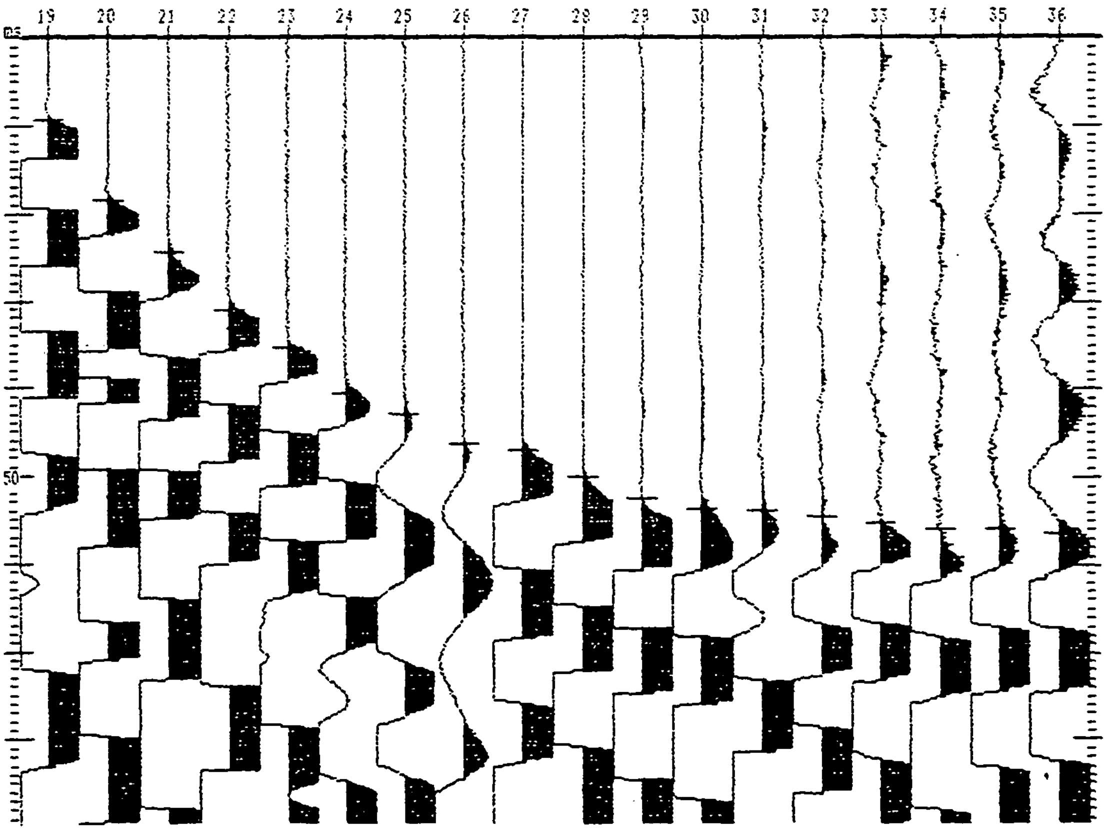
Profile ID:	TAMWA10/K4/R	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	13:04
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY CAALM RESIN PLATE	Start offset:	1.5 m

Channel:2



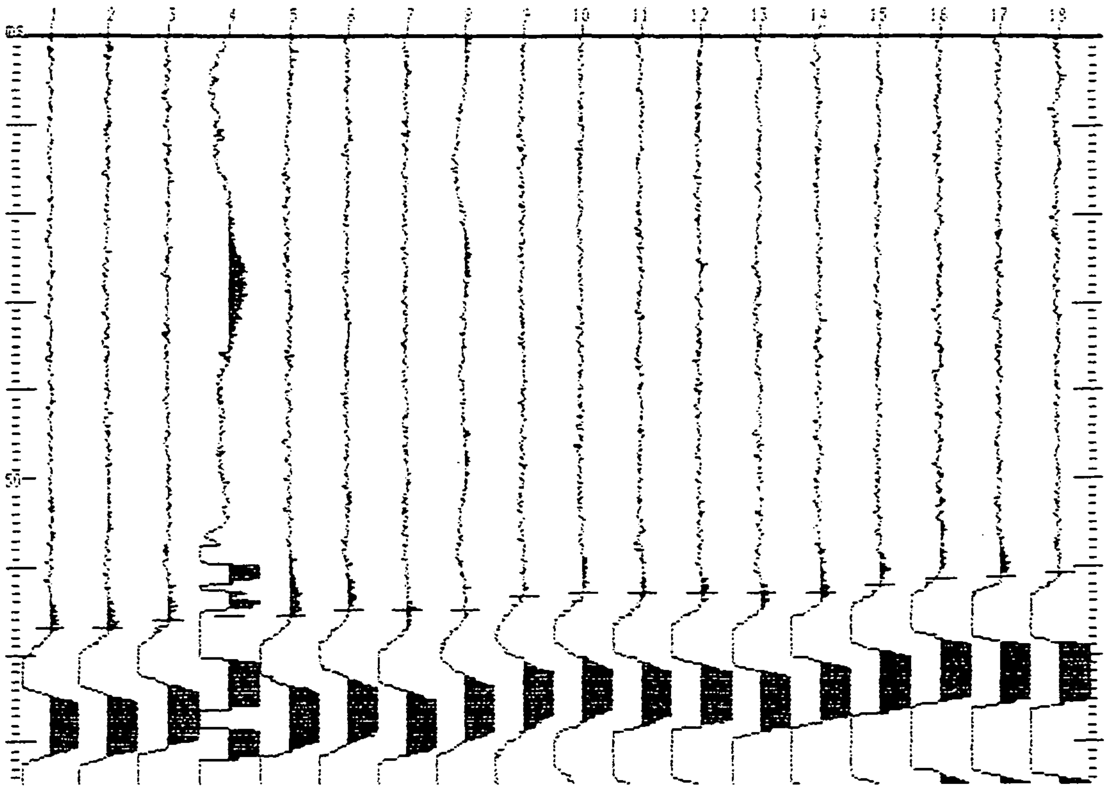
Profile ID:	TAMWA10/K4/R	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	13:04
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY CAALM RESIN PLATE	Start offset:	1.5 m

Channel:2



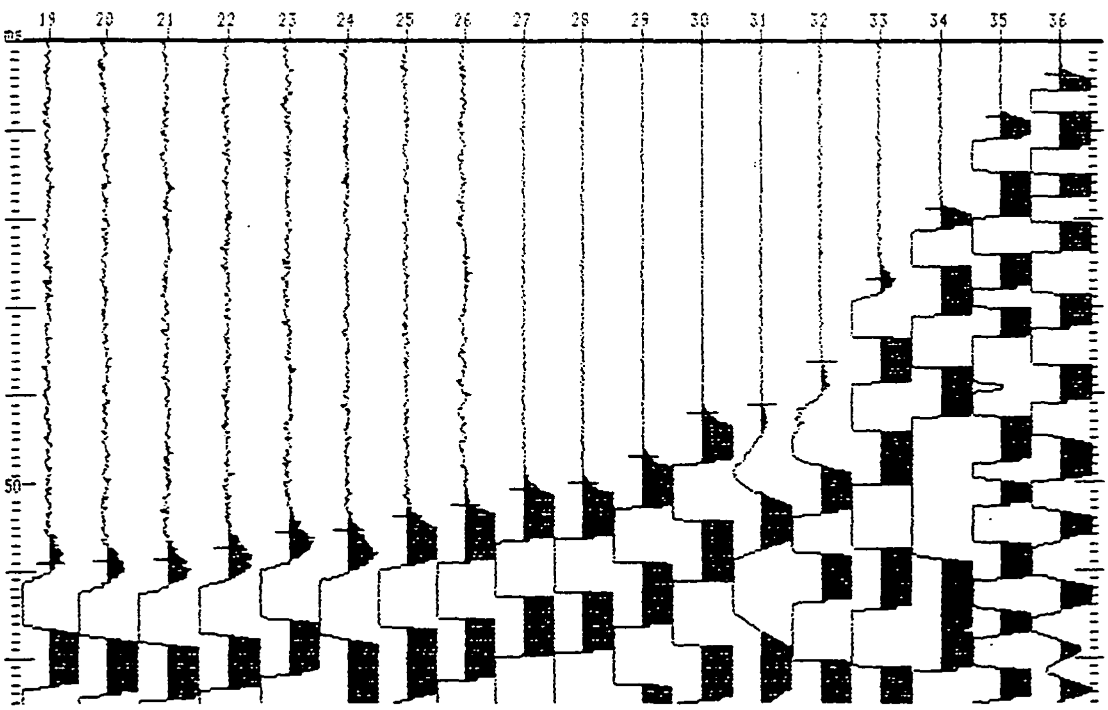
Profile ID:	TAMWA10/K4/R	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	13:04
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY CAALM RESIN PLATE	Start offset:	1.5 m

Channel:3



Profile ID:	TAMWA10/K4/R	Method:	Automatic
Project:	BGS	Date:	94/02/21
Customer:	ODA	Created:	13:04
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY CAALM RESIN PLATE	Start offset:	1.5 m

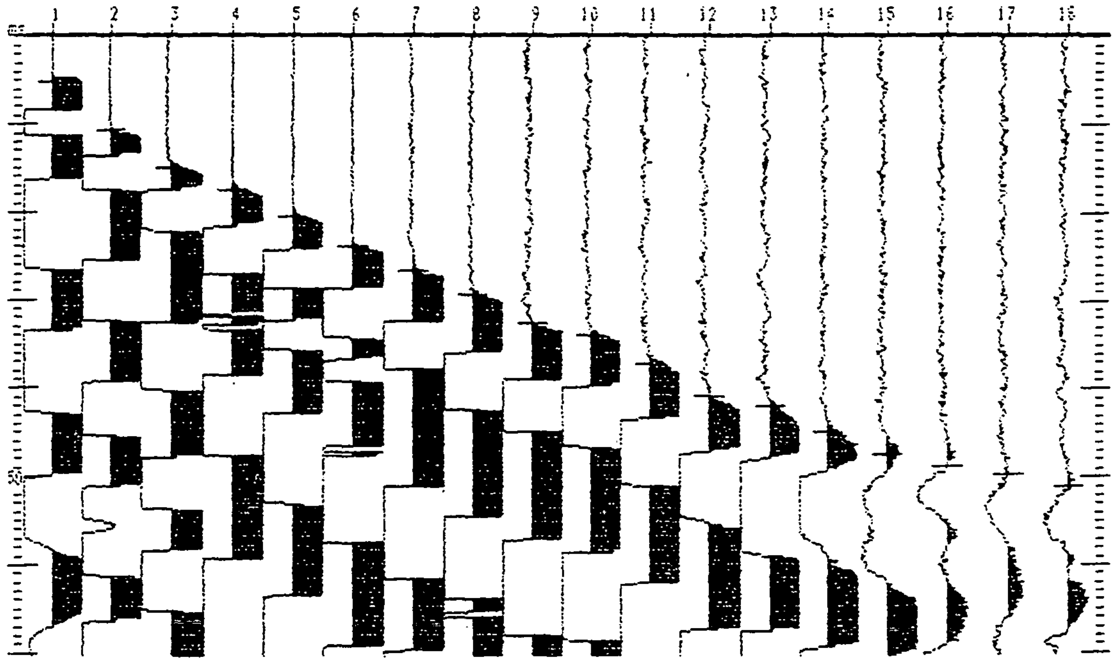
Channel:3



Profile ID: TAMWA11/H
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/22
Created: 10:13
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

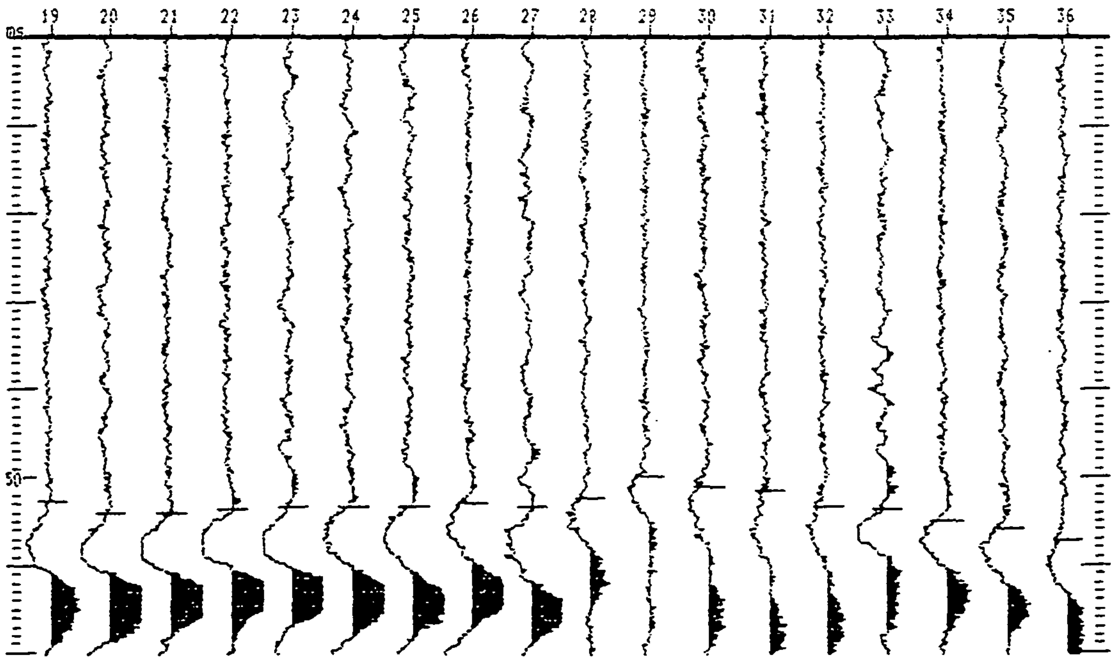
Channel:1



Profile ID: TAMWA11/H
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

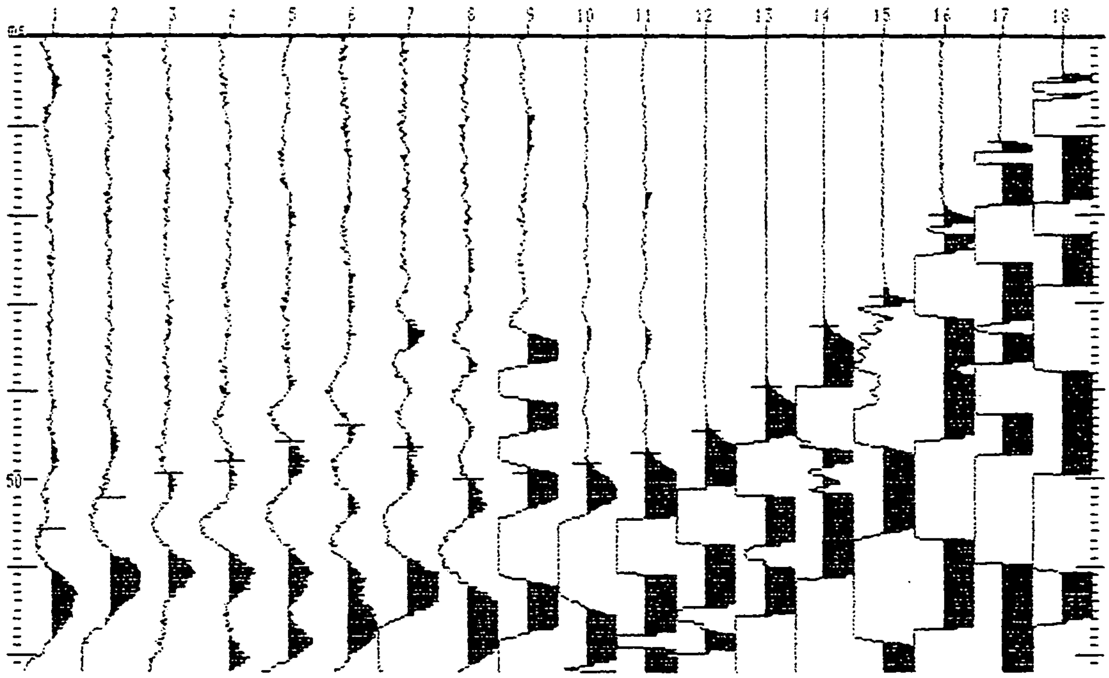
Method: Automatic
Date: 94/02/22
Created: 10:13
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:1



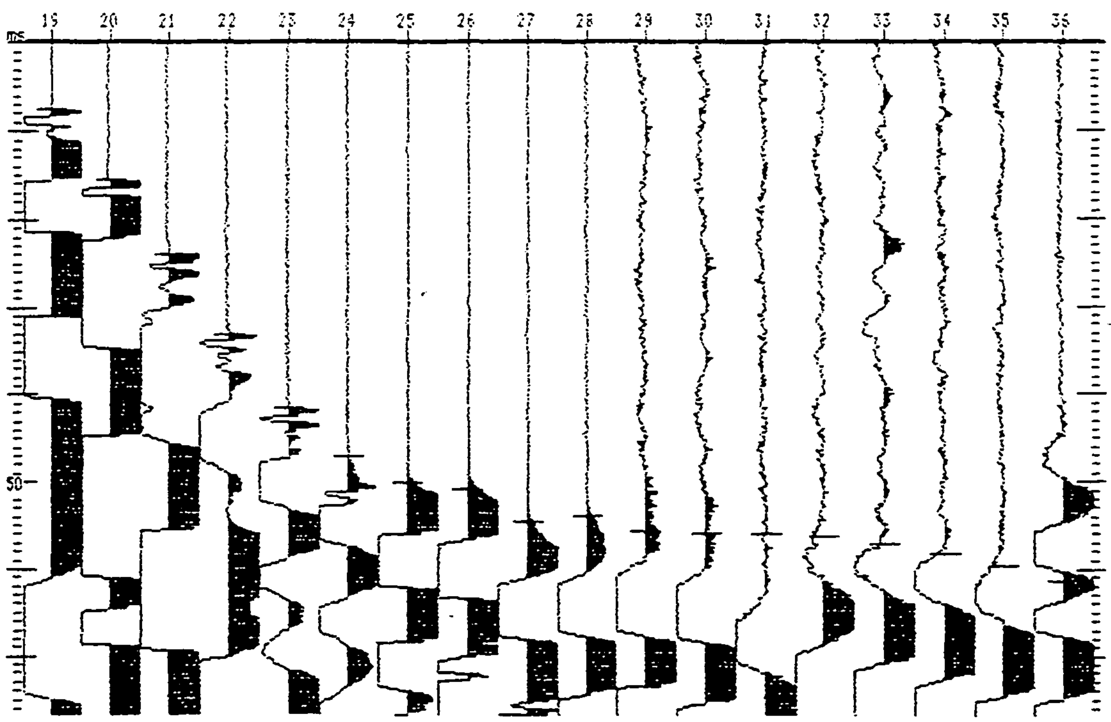
Profile ID:	TAMWA11/H	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	10:13
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:2



Profile ID:	TAMWA11/H	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	10:13
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

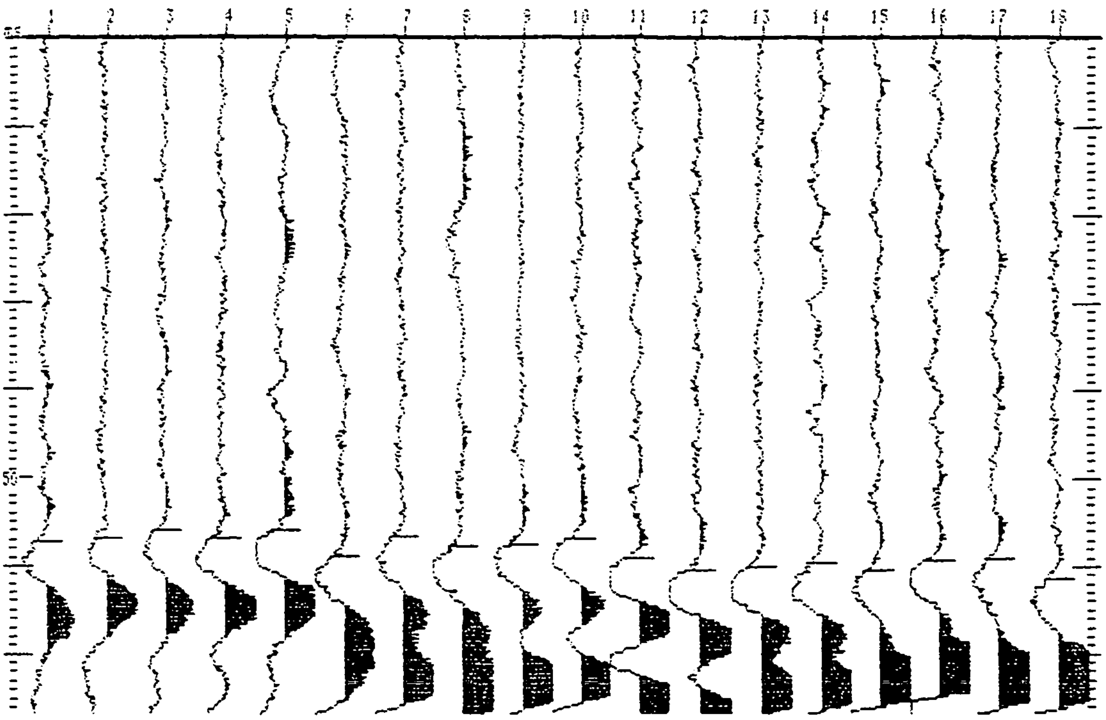
Channel:2



Profile ID: TAMWA11/H
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/22
Created: 10:13
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

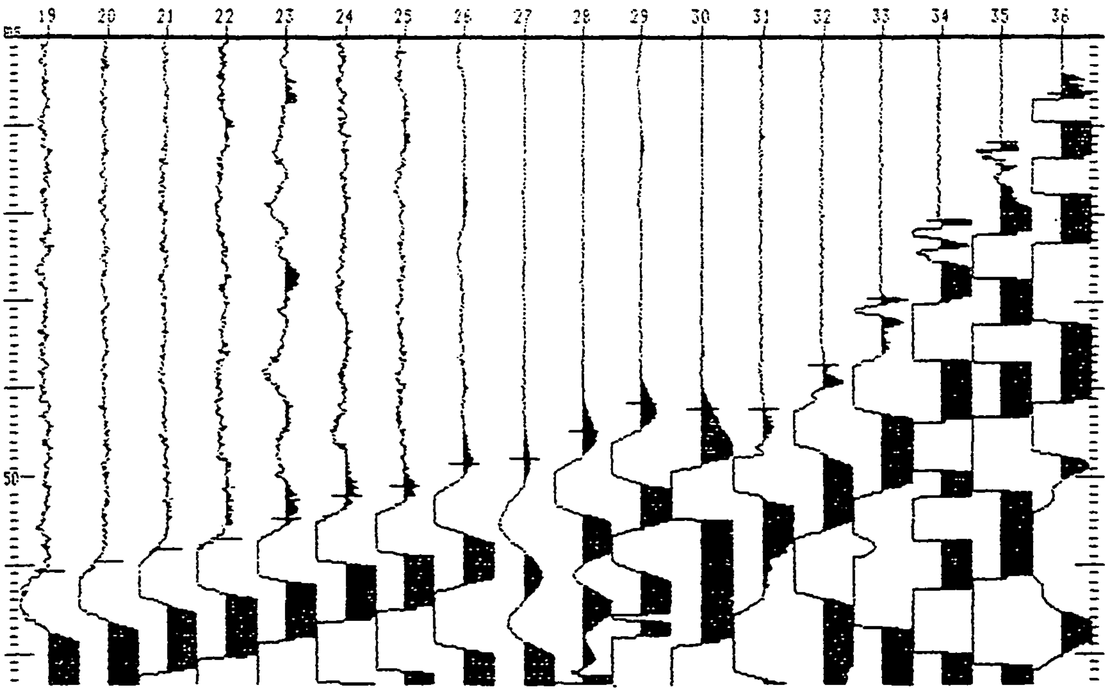
Channel:3



Profile ID: TAMWA11/H
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

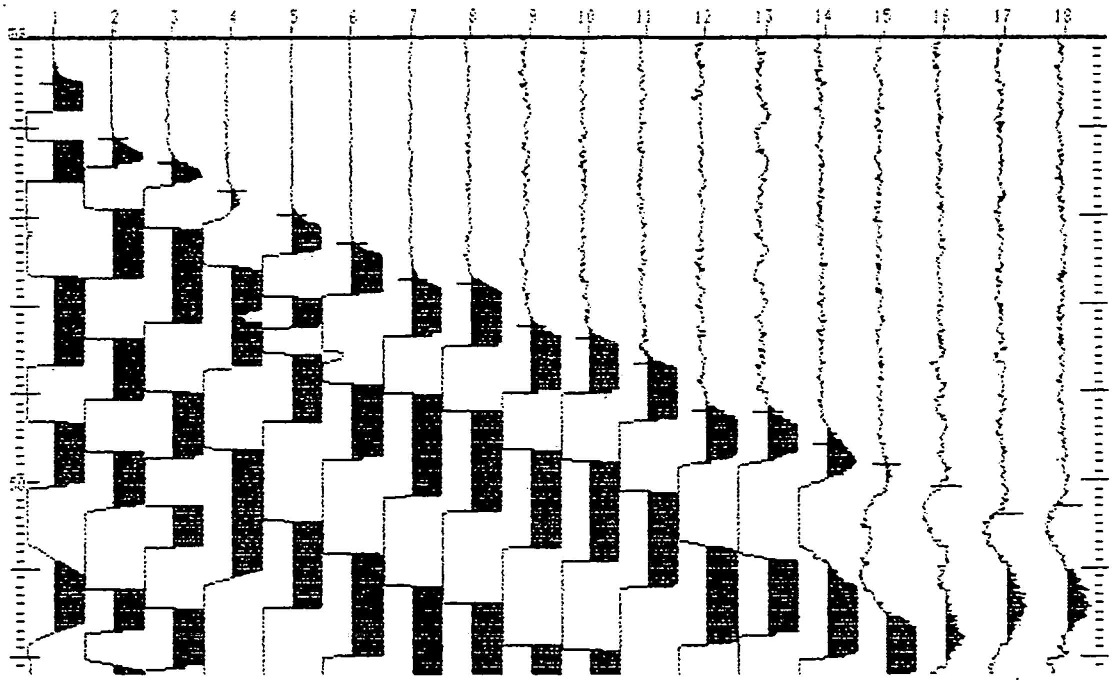
Method: Automatic
Date: 94/02/22
Created: 10:13
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:3



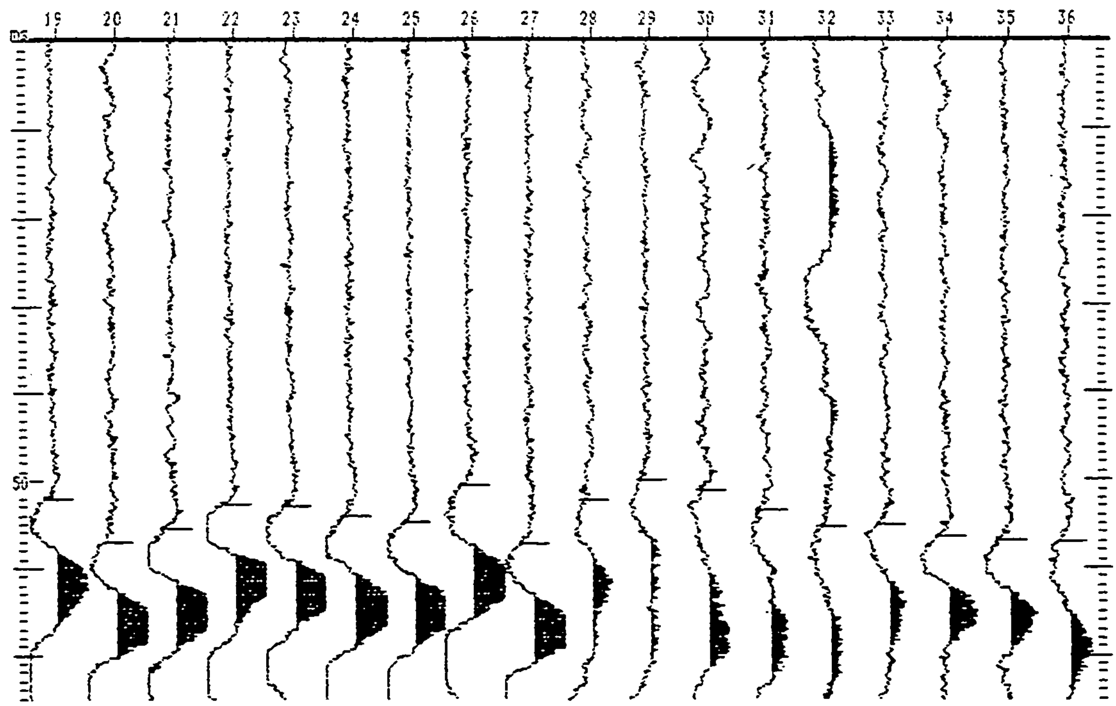
Profile ID:	TAWMA12/H/R	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	12:14
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY RESIN PLATE	Start offset:	1.5 m

Channel:1



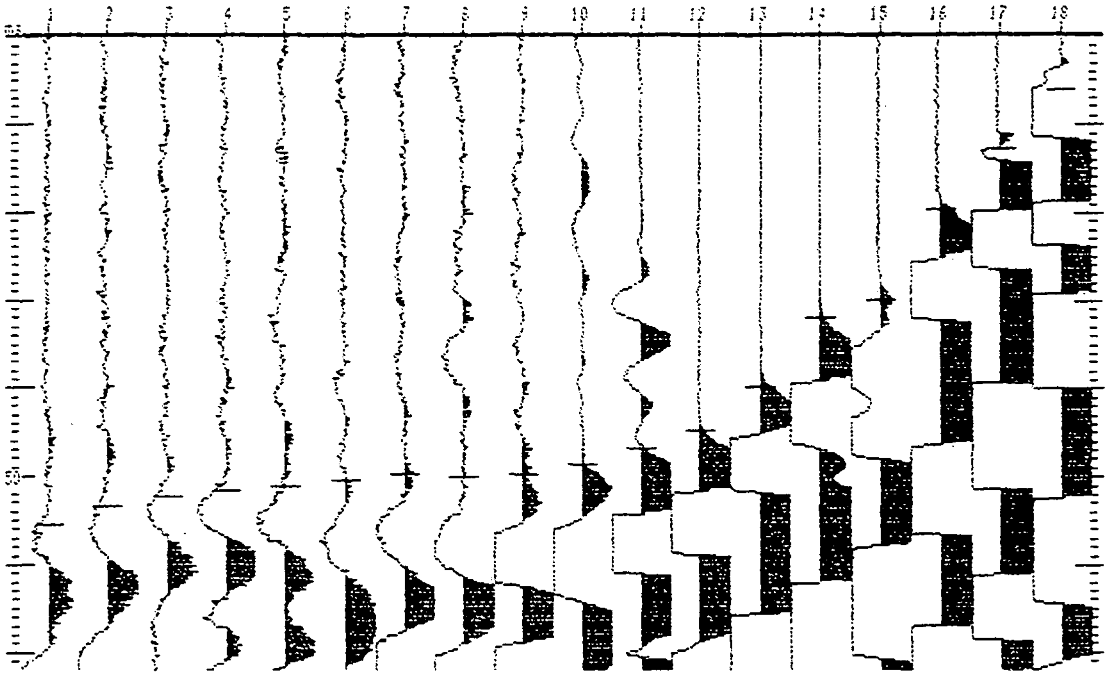
Profile ID:	TAWMA12/H/R	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	12:14
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY RESIN PLATE	Start offset:	1.5 m

Channel:1



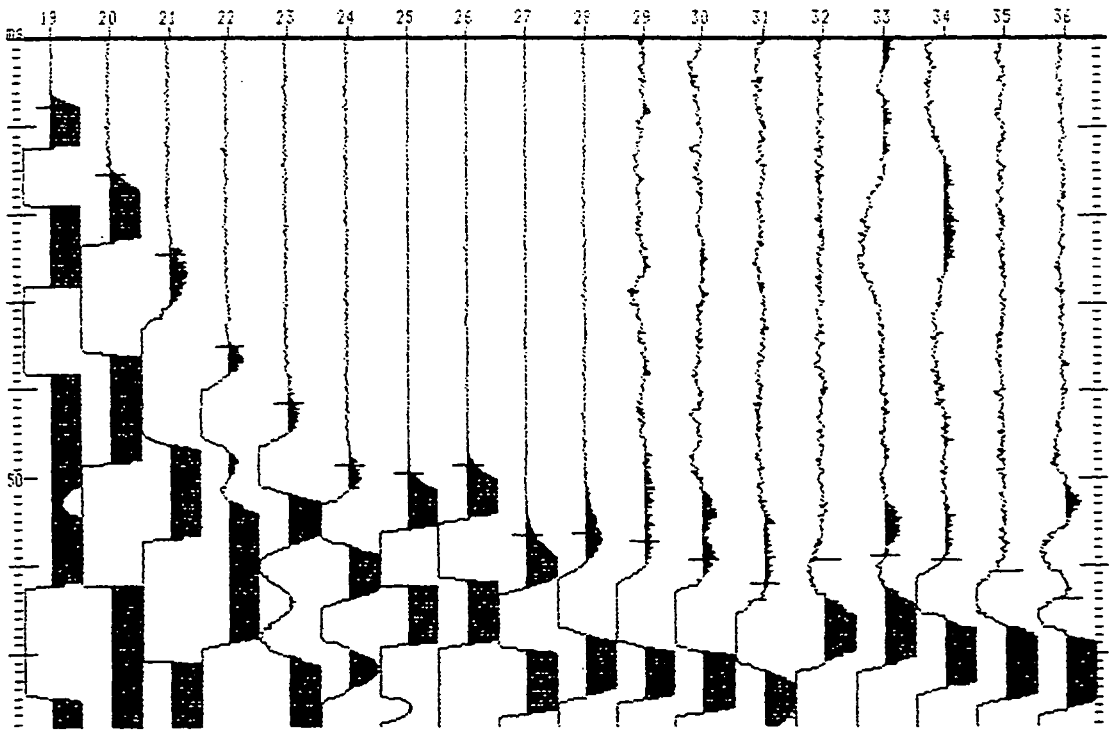
Profile ID:	TAWMA12/H/R	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	12:14
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY RESIN PLATE	Start offset:	1.5 m

Channel:2



Profile ID:	TAWMA12/H/R	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	12:14
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY RESIN PLATE	Start offset:	1.5 m

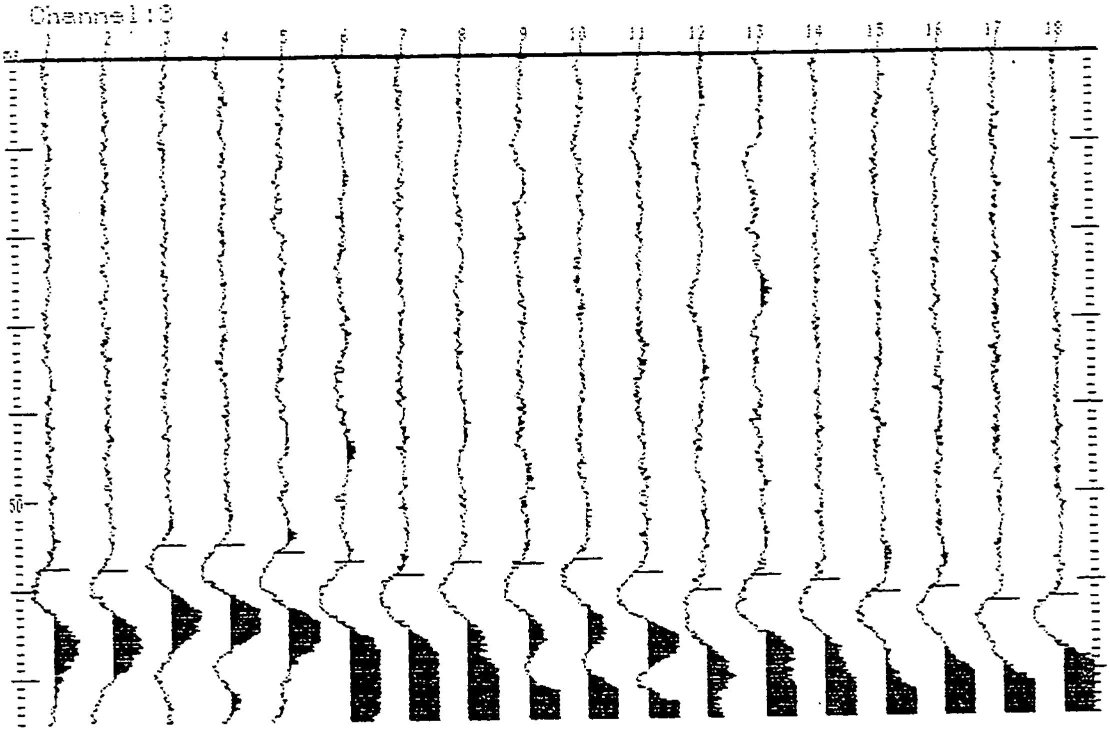
Channel:2



Profile ID: TAWMA12/H/R
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY RESIN PLATE

Method: Automatic
Date: 94/02/22
Created: 12:14
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

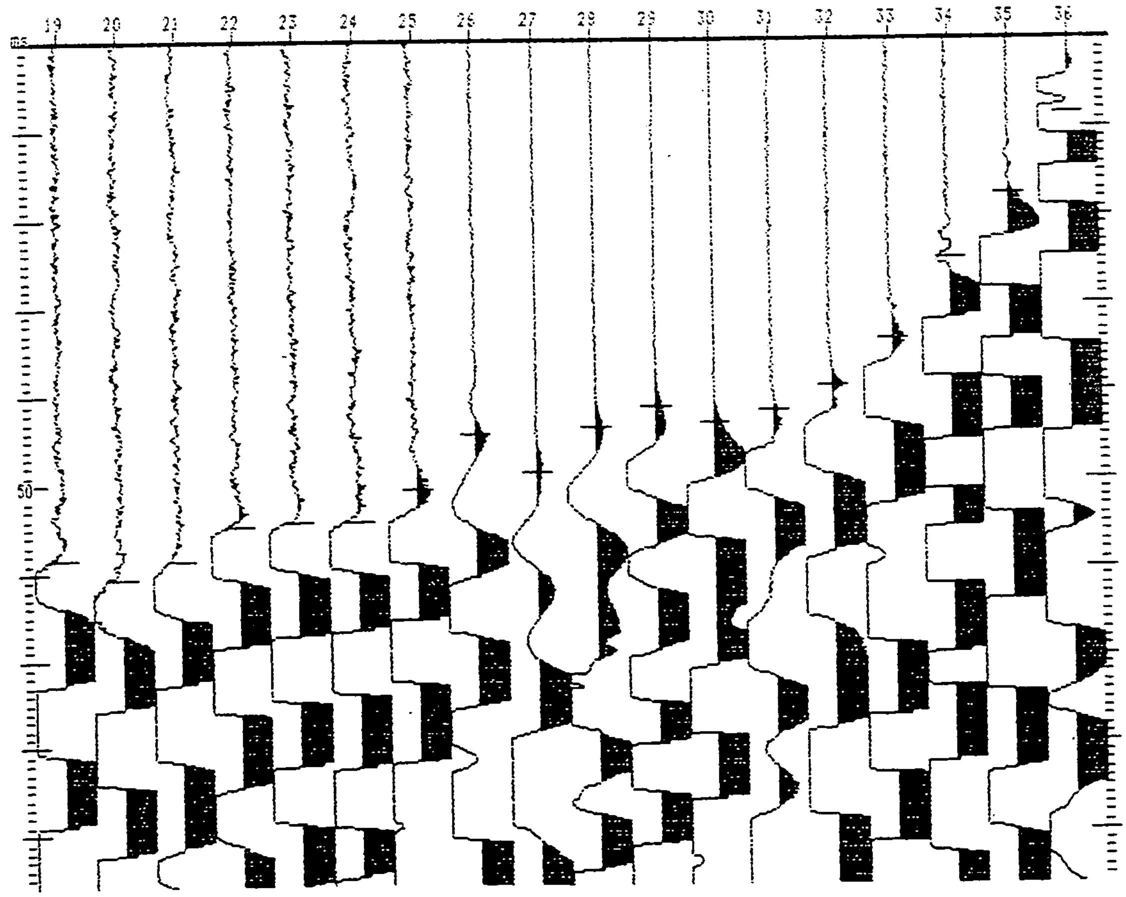
Channel:3



Profile ID: TAWMA12/H/R
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY RESIN PLATE

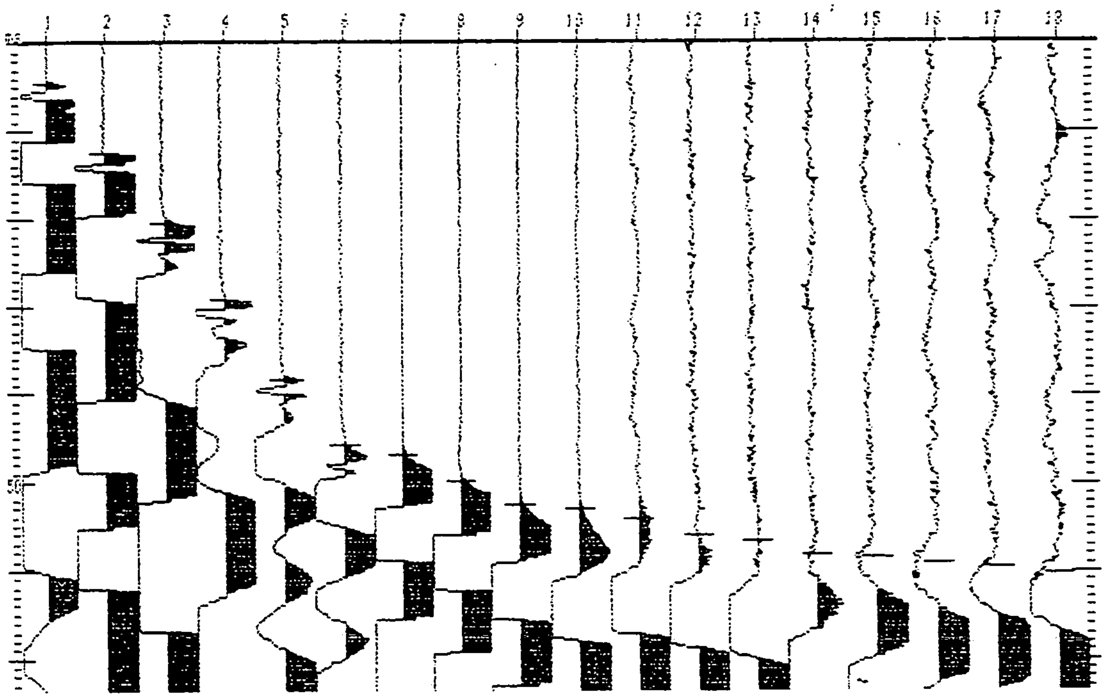
Method: Automatic
Date: 94/02/22
Created: 12:14
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:3



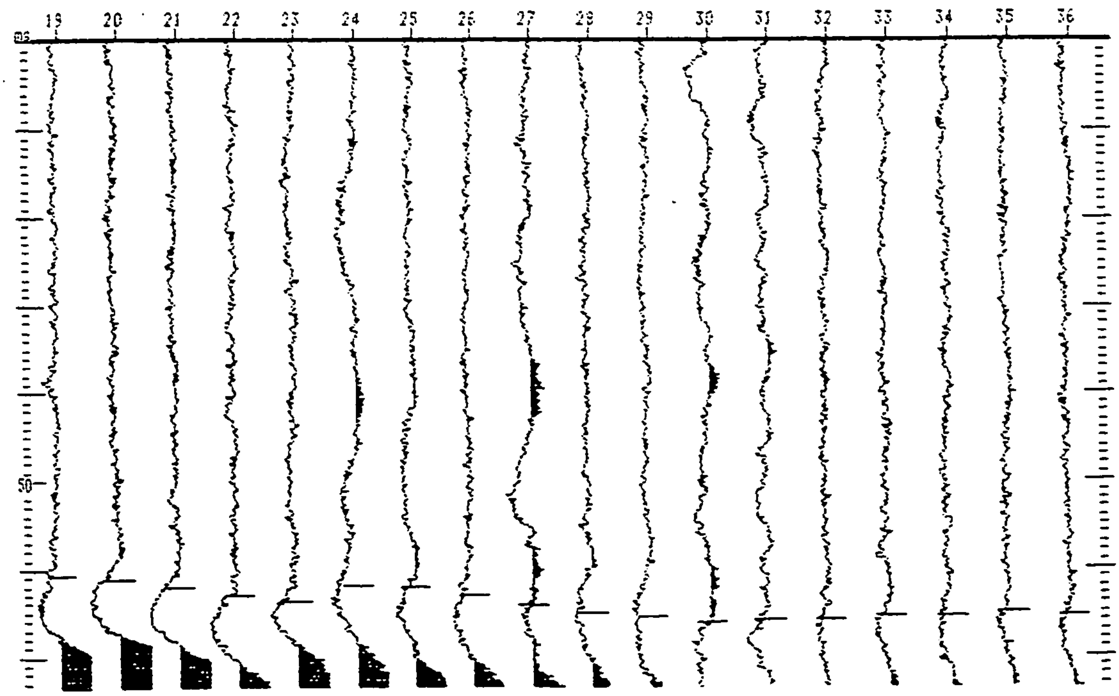
Profile ID:	TAMWA13/H+50S	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	14:21
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



Profile ID:	TAMWA13/H+50S	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	14:21
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

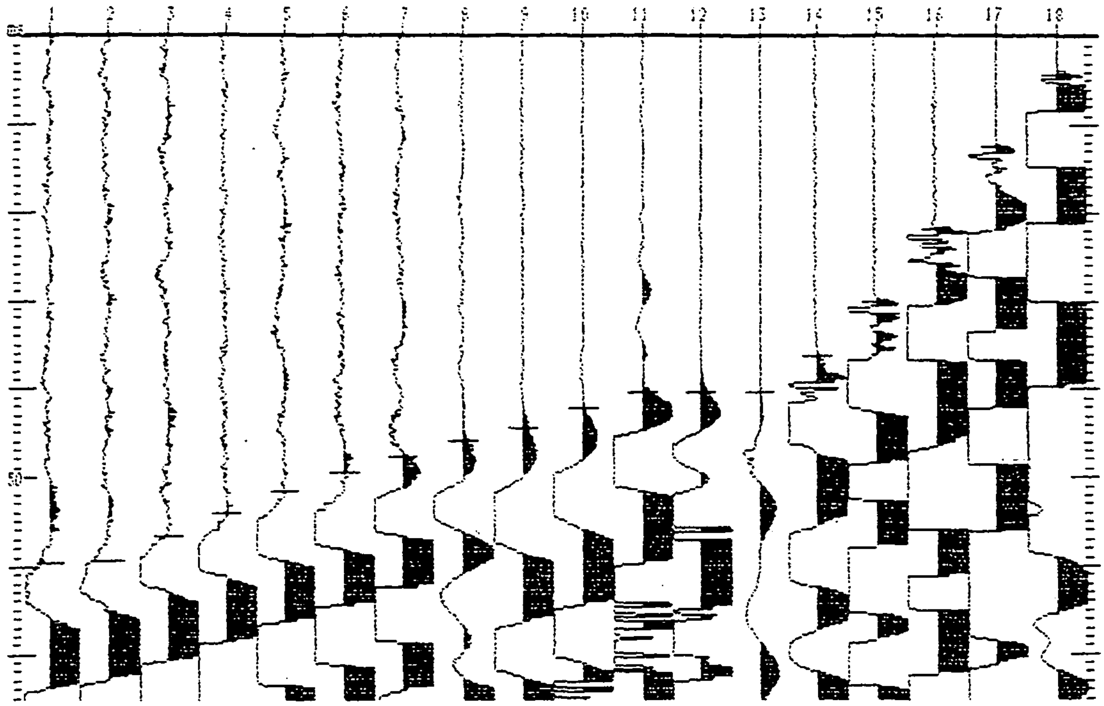
Channel:1



Profile ID: TAMWA13/H+50S
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/22
Created: 14:21
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

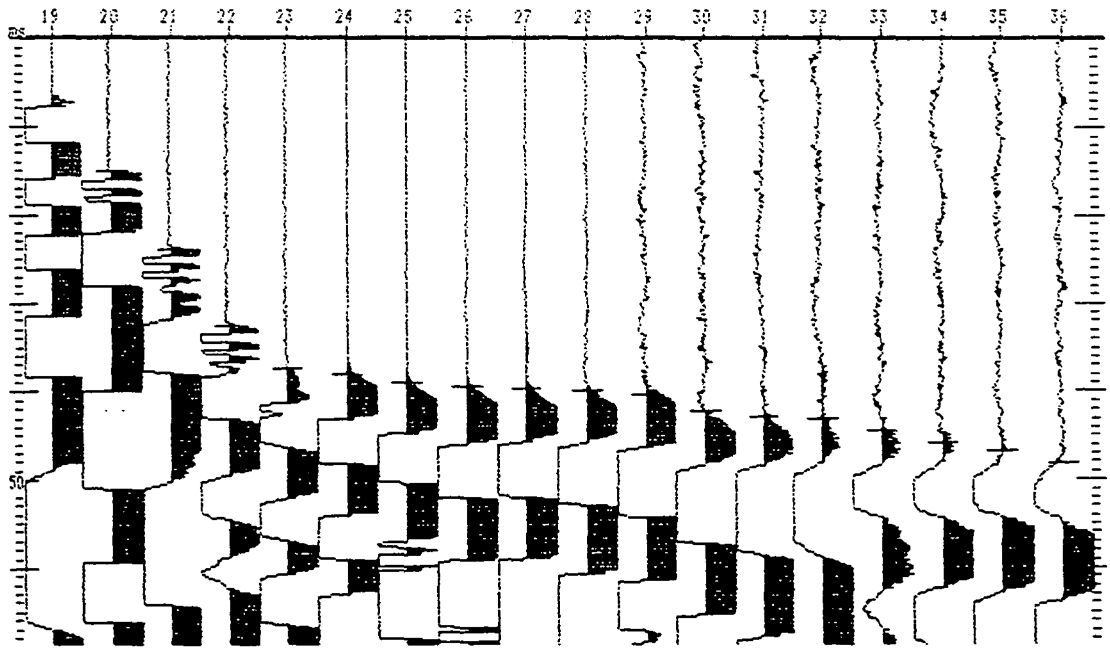
Channel:2



Profile ID: TAMWA13/H+50S
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

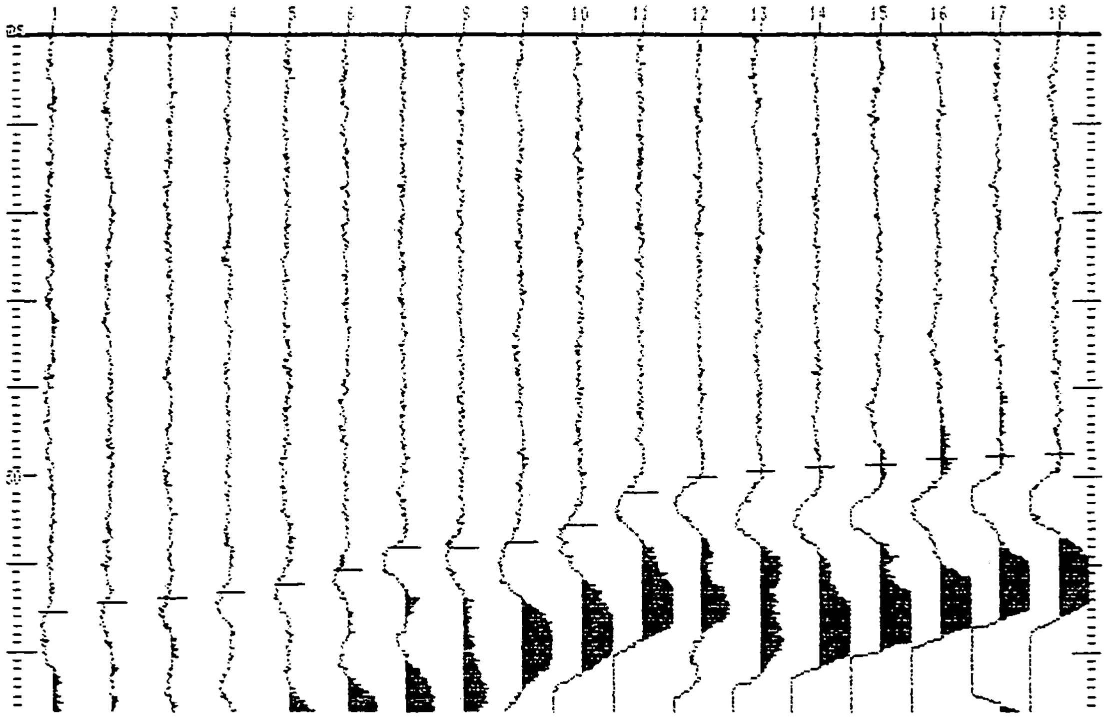
Method: Automatic
Date: 94/02/22
Created: 14:21
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:2



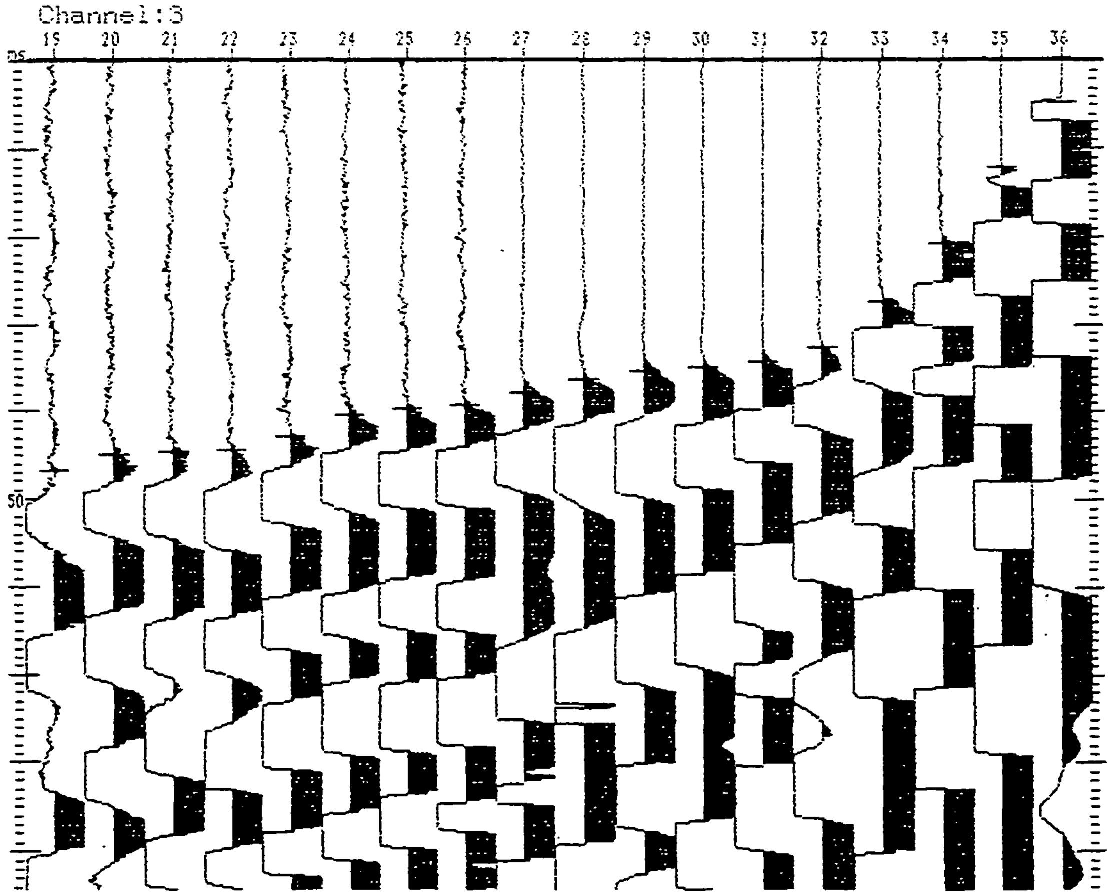
Profile ID:	TAMWA13/H+508	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	14:21
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



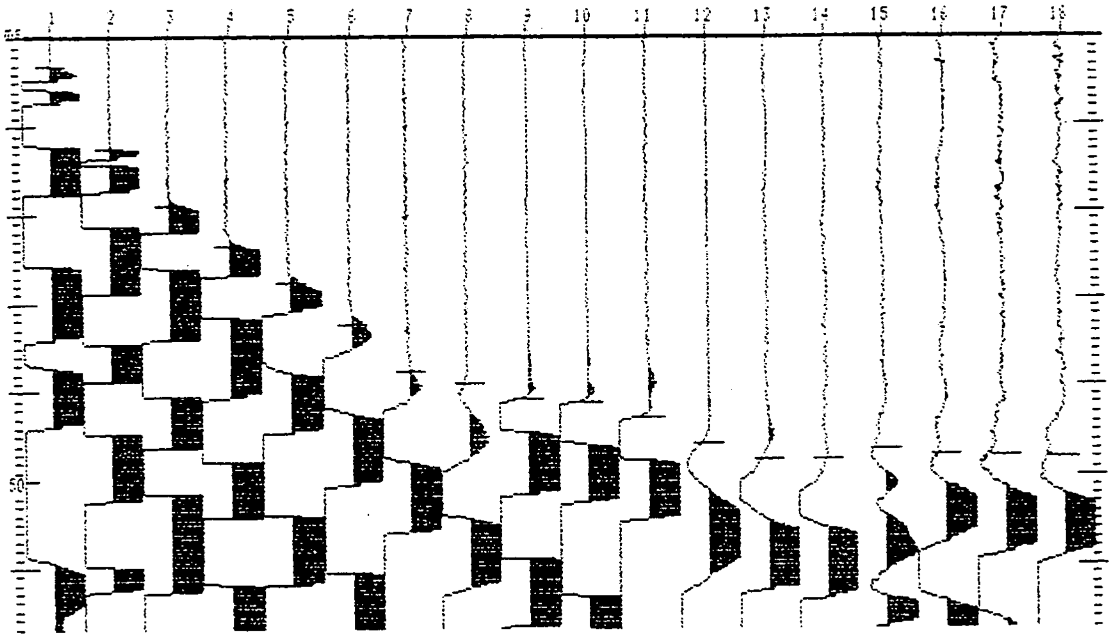
Profile ID:	TAMWA13/H+508	Method:	Automatic
Project:	BGS	Date:	94/02/22
Customer:	ODA	Created:	14:21
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



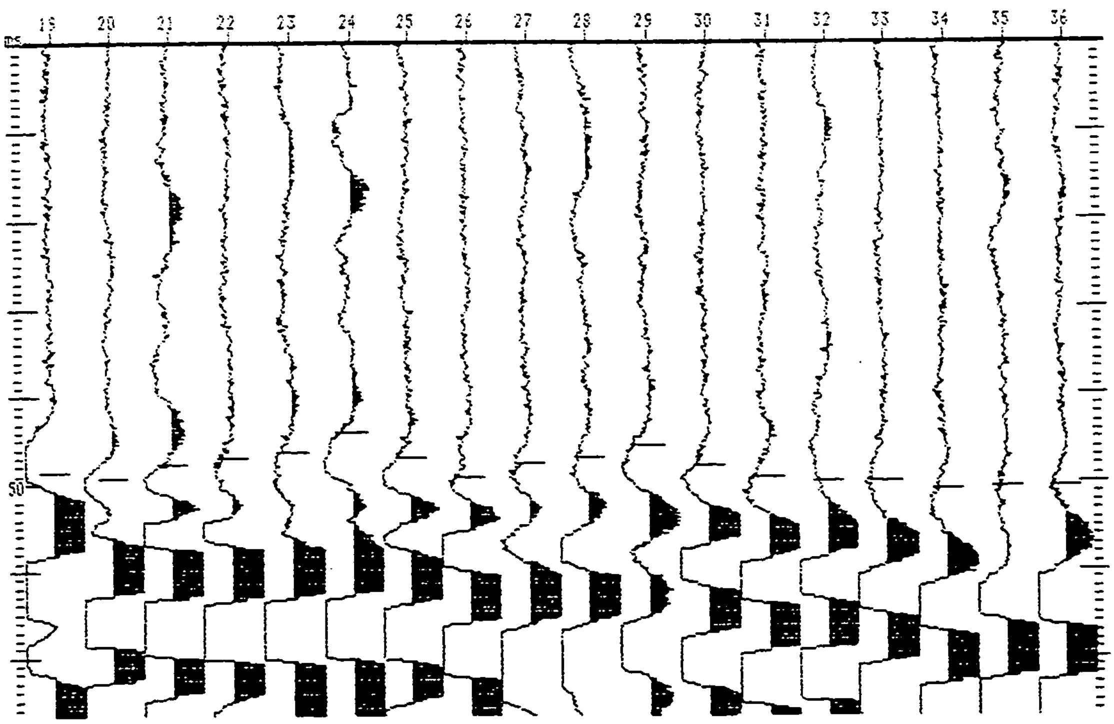
Profile ID:	TAMWA14/N1	Method:	Automatic
Project:	BGS	Date:	94/02/23
Customer:	ODA	Created:	08:50
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



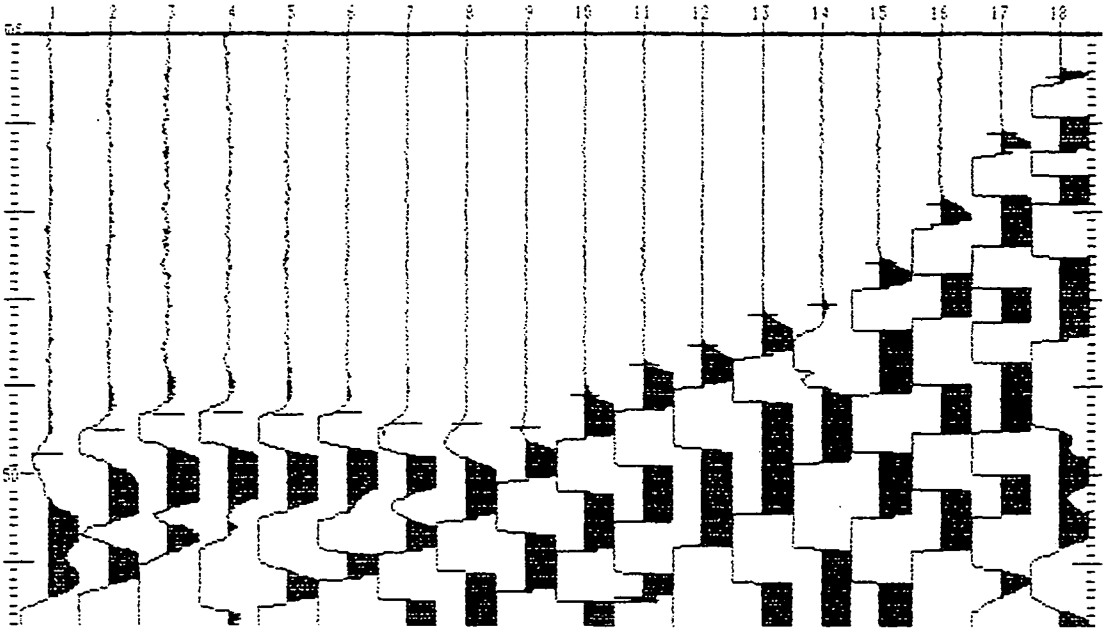
Profile ID:	TAMWA14/N1	Method:	Automatic
Project:	BGS	Date:	94/02/23
Customer:	ODA	Created:	08:50
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:1



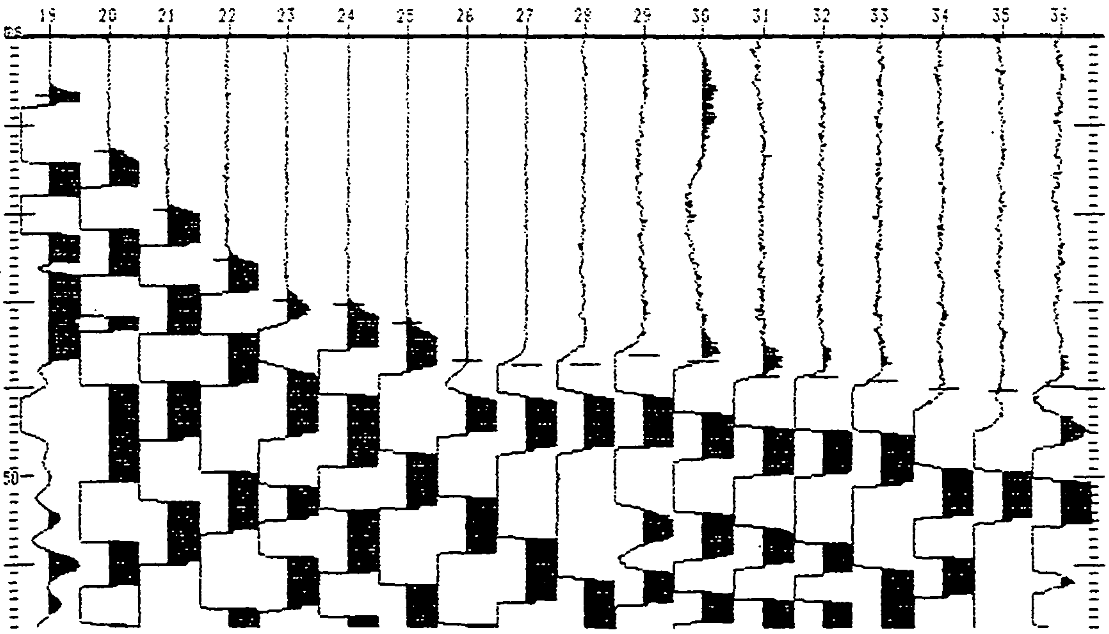
Profile ID: TAMWA14/N1 | Method: Automatic
Project: BGS | Date: 94/02/23
Customer: ODA | Created: 08:50
Cust. ref.: ODA | Geoph. spacing: 54.0 m
Operator: JEFF AND PHILL | Shot spacing: 3.0 m
Comments: CLOUDY WINDY METAL PLATE | Start offset: 1.5 m

Channel:2



Profile ID: TAMWA14/N1 | Method: Automatic
Project: BGS | Date: 94/02/23
Customer: ODA | Created: 08:50
Cust. ref.: ODA | Geoph. spacing: 54.0 m
Operator: JEFF AND PHILL | Shot spacing: 3.0 m
Comments: CLOUDY WINDY METAL PLATE | Start offset: 1.5 m

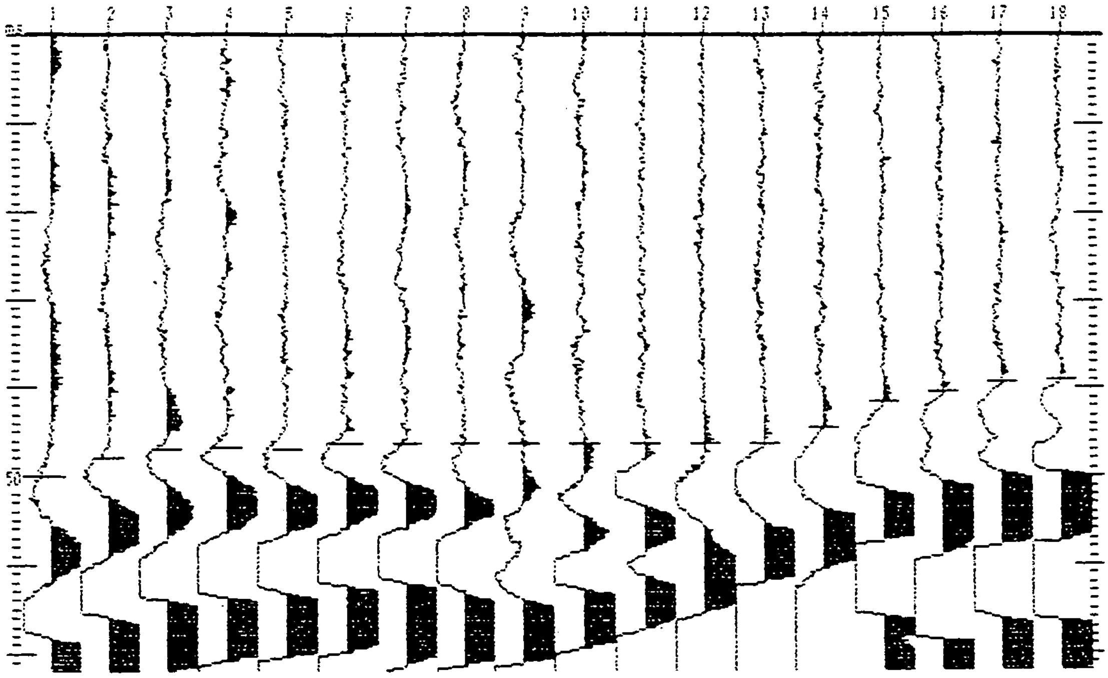
Channel:2



Profile ID: TAMWA14/N1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 08:50
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

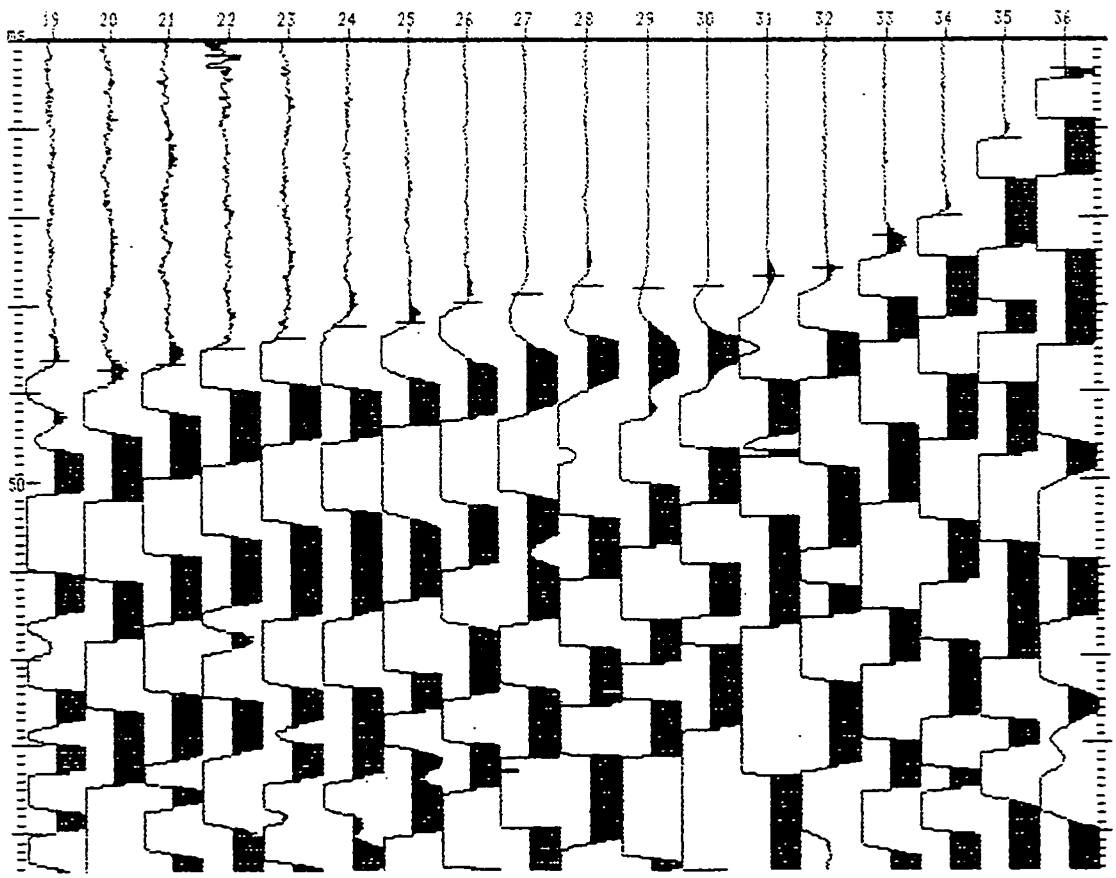
Channel:3



Profile ID: TAMWA14/N1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 08:50
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

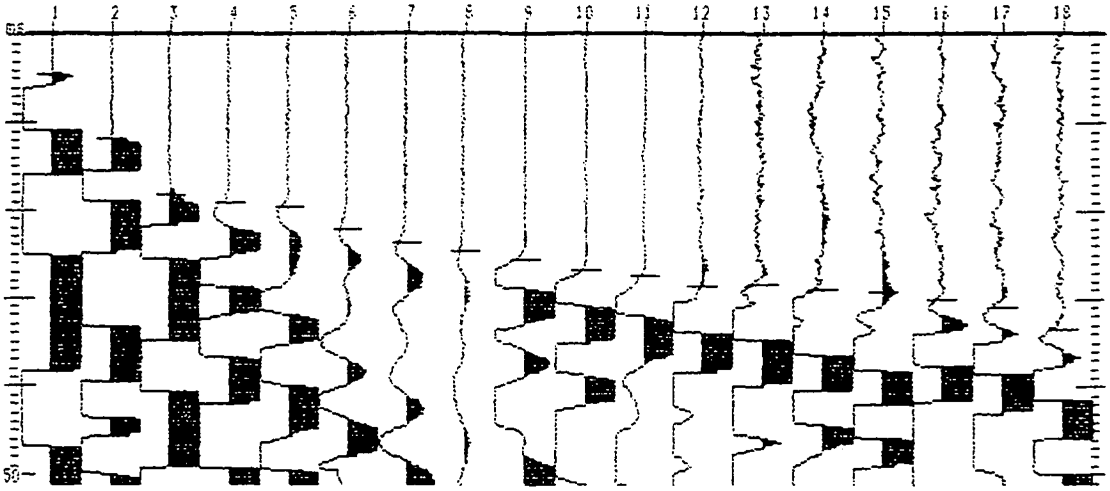
Channel:3



Profile ID: TAMWA15/RC
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 11:22
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

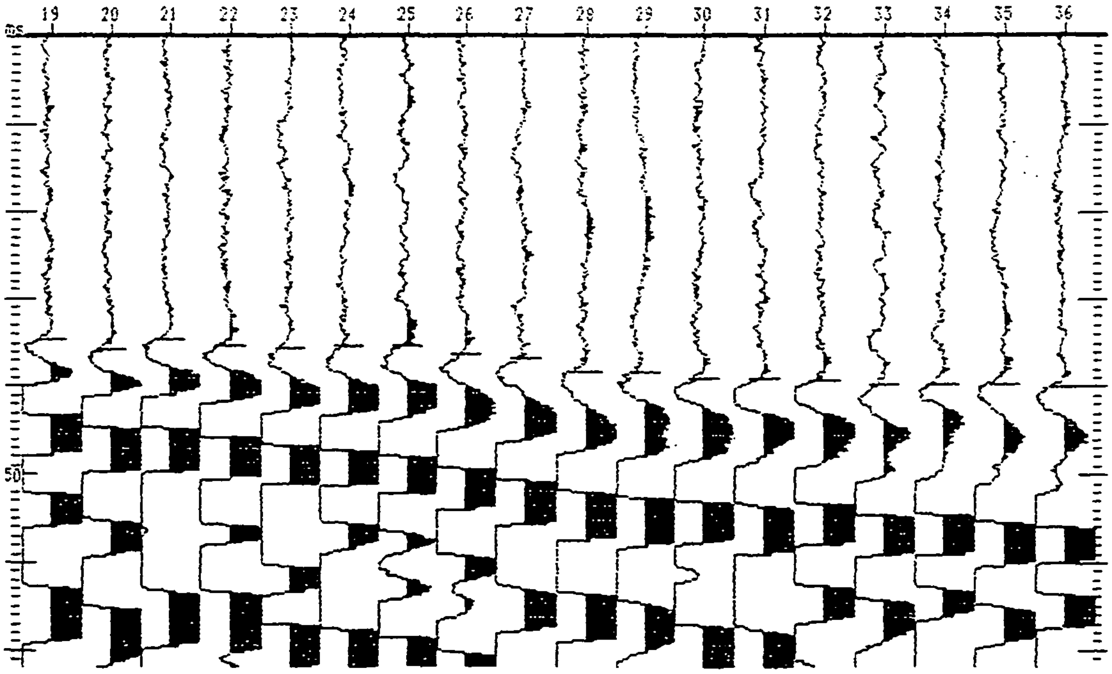
Channel:1



Profile ID: TAMWA15/RC
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 11:22
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

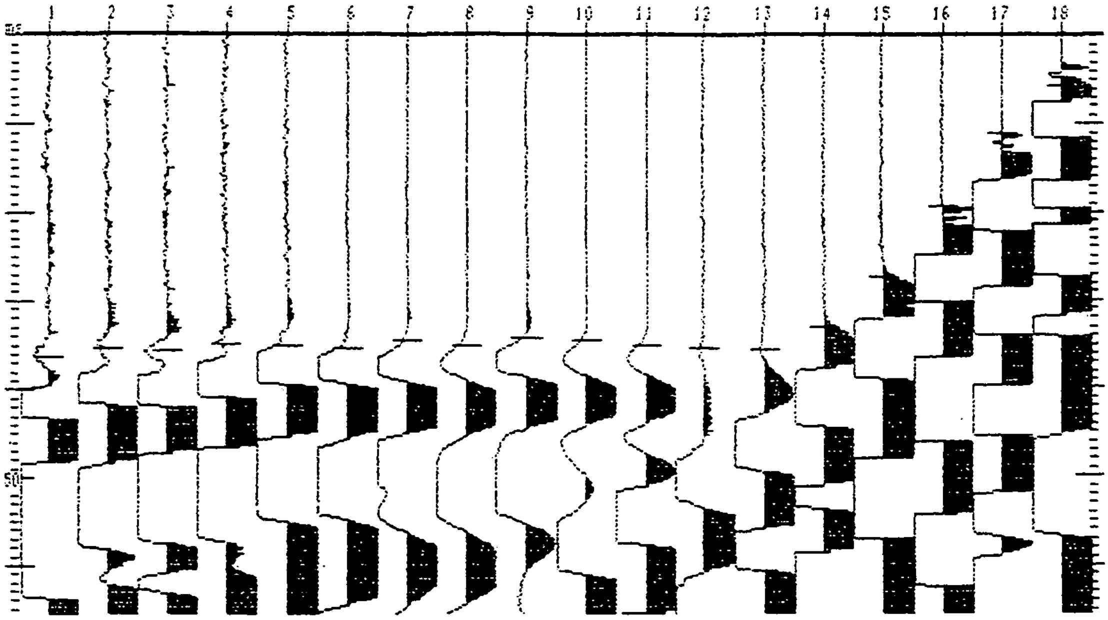
Channel:1



Profile ID: TAMWA15/RC
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 11:22
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

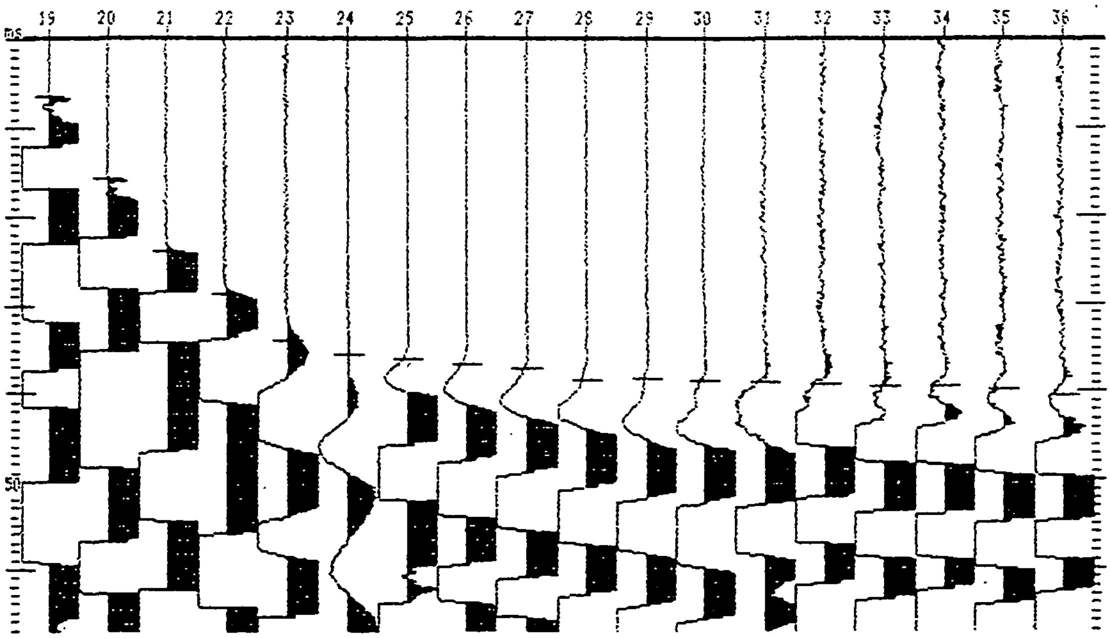
Channel:2



Profile ID: TAMWA15/RC
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

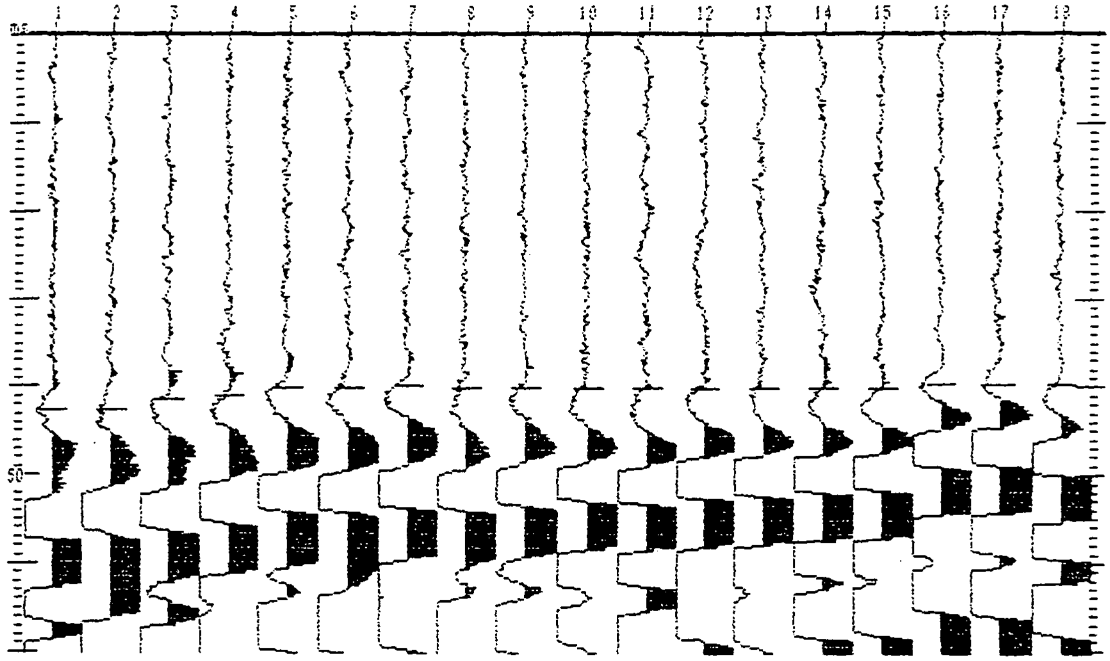
Method: Automatic
Date: 94/02/23
Created: 11:22
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:2



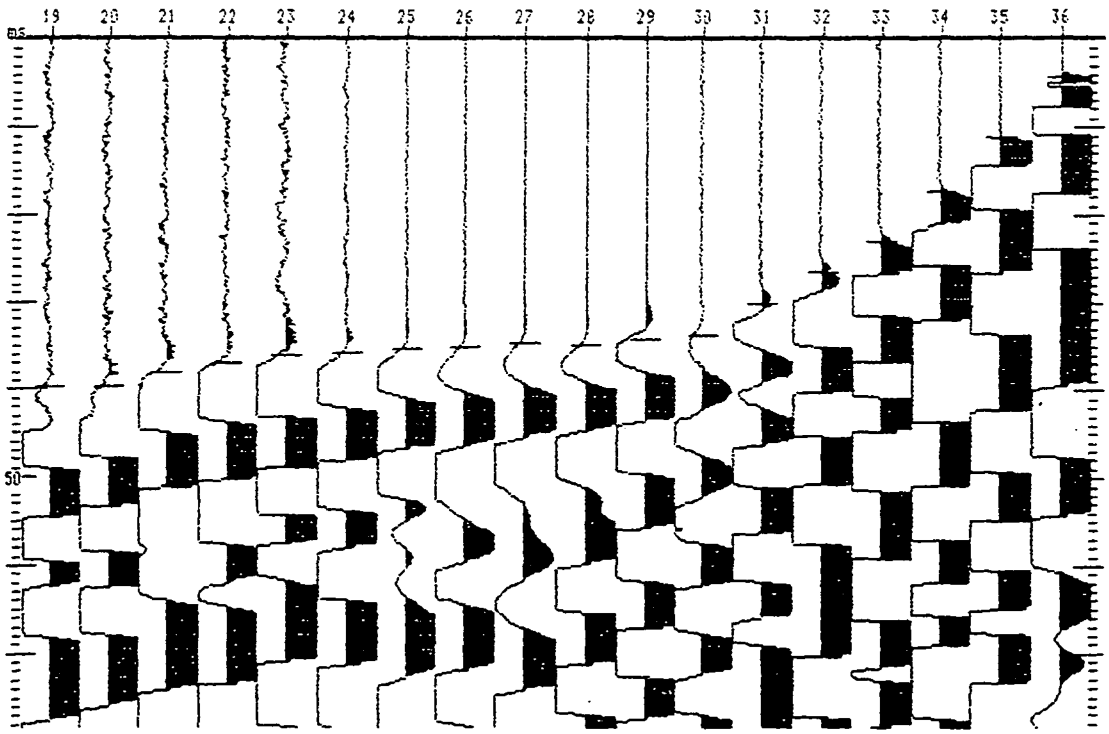
Profile ID:	TAMWA15/RC	Method:	Automatic
Project:	BGS	Date:	94/02/23
Customer:	ODA	Created:	11:22
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

Channel:3



Profile ID:	TAMWA15/RC	Method:	Automatic
Project:	BGS	Date:	94/02/23
Customer:	ODA	Created:	11:22
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY METAL PLATE	Start offset:	1.5 m

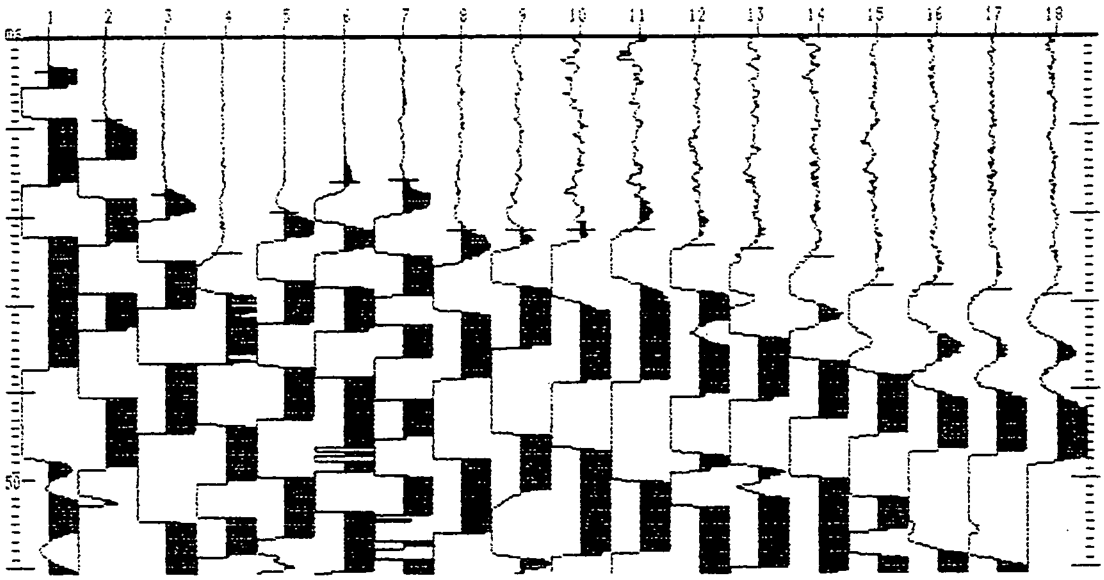
Channel:3



Profile ID: TAMWA16/J1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 13:05
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

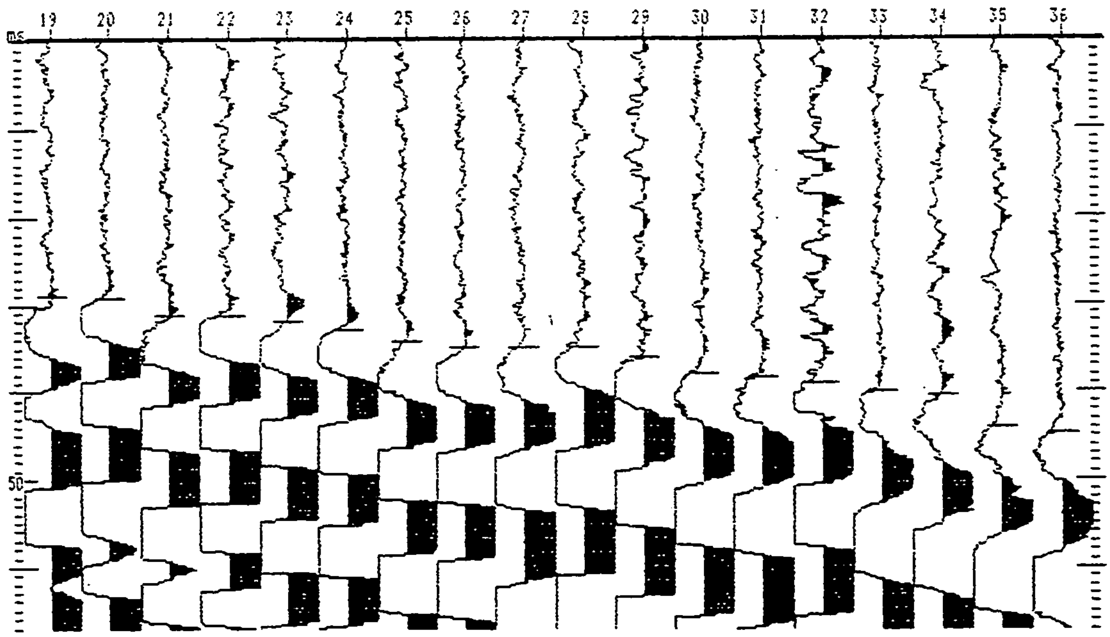
Channel:1



Profile ID: TAMWA16/J1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 13:05
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

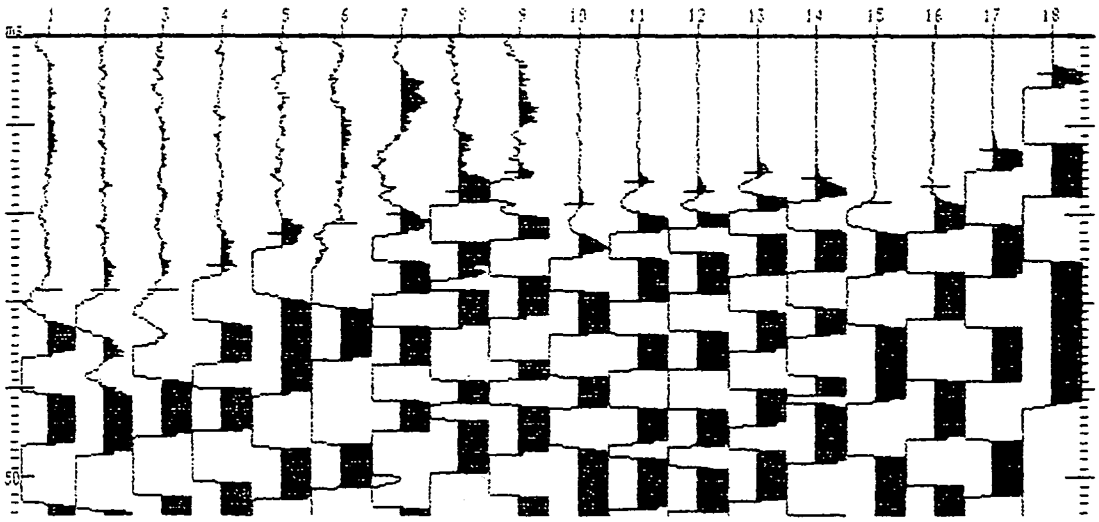
Channel:1



Profile ID: TAMWA16/J1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 13:05
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

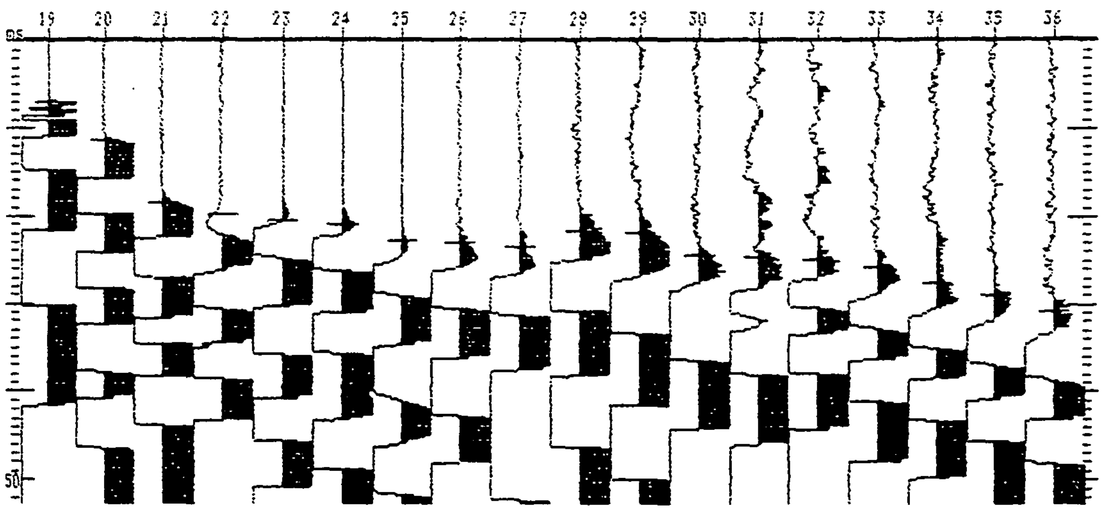
Channel:2



Profile ID: TAMWA16/J1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 13:05
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

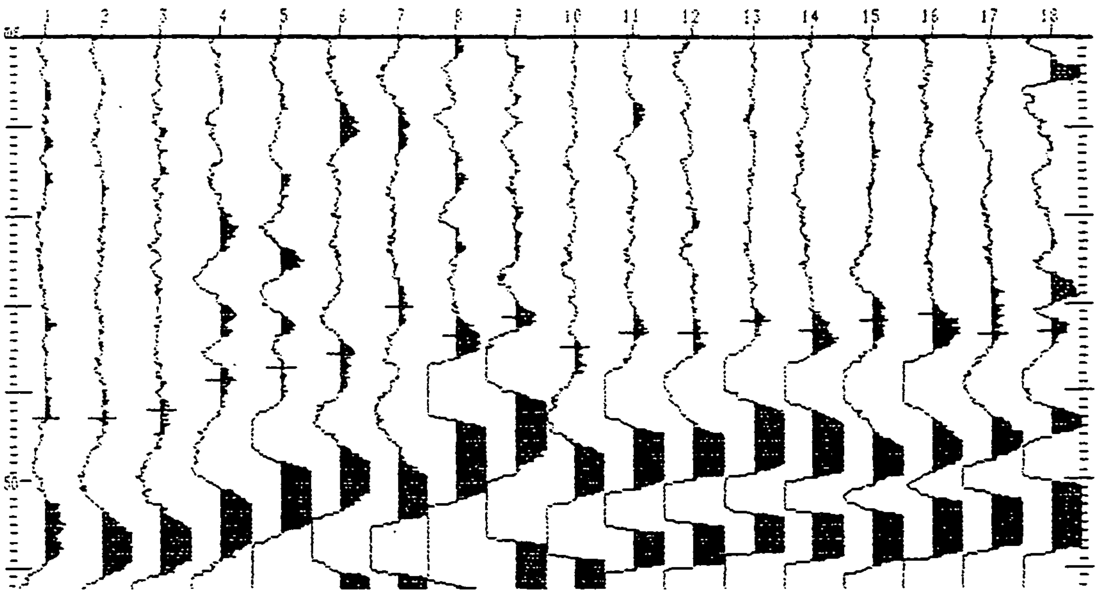
Channel:2



Profile ID: TAMWA16/J1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

Method: Automatic
Date: 94/02/23
Created: 13:05
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

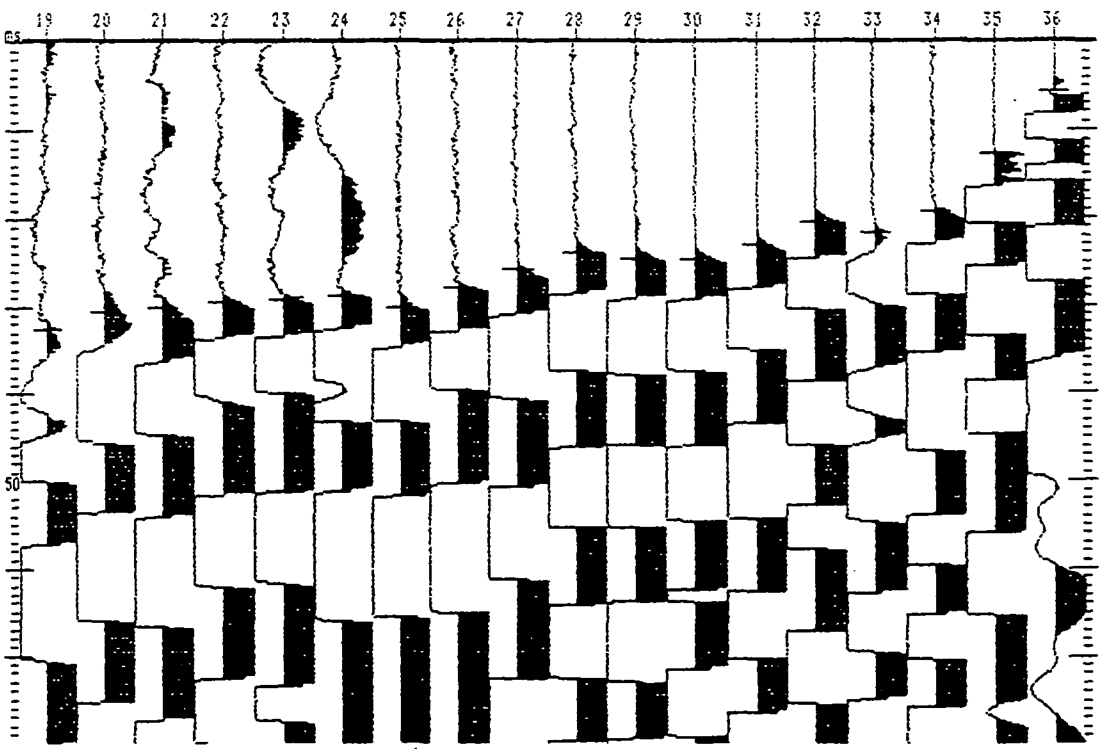
Channel:3



Profile ID: TAMWA16/J1
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY METAL PLATE

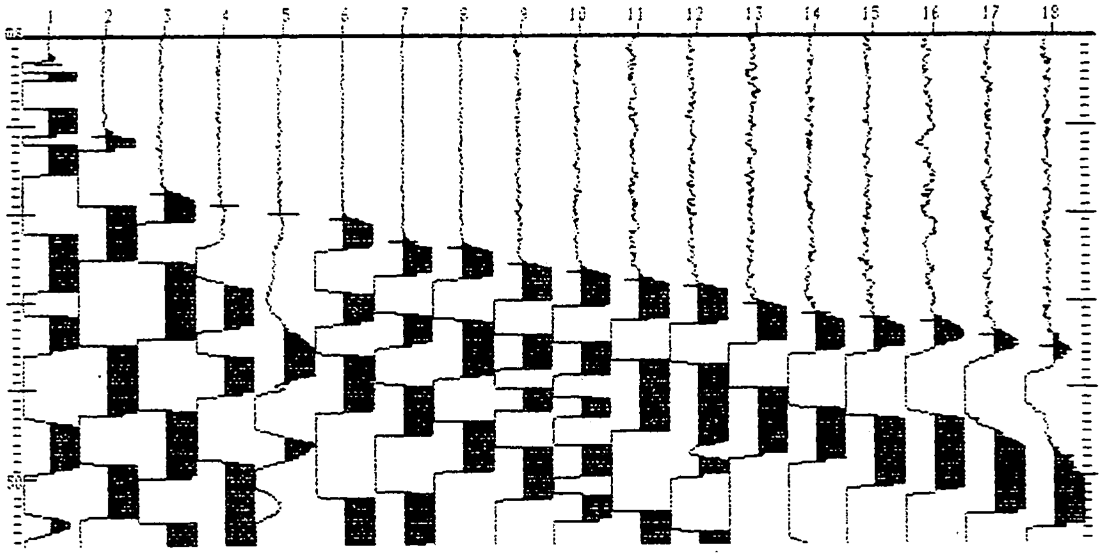
Method: Automatic
Date: 94/02/23
Created: 13:05
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:3



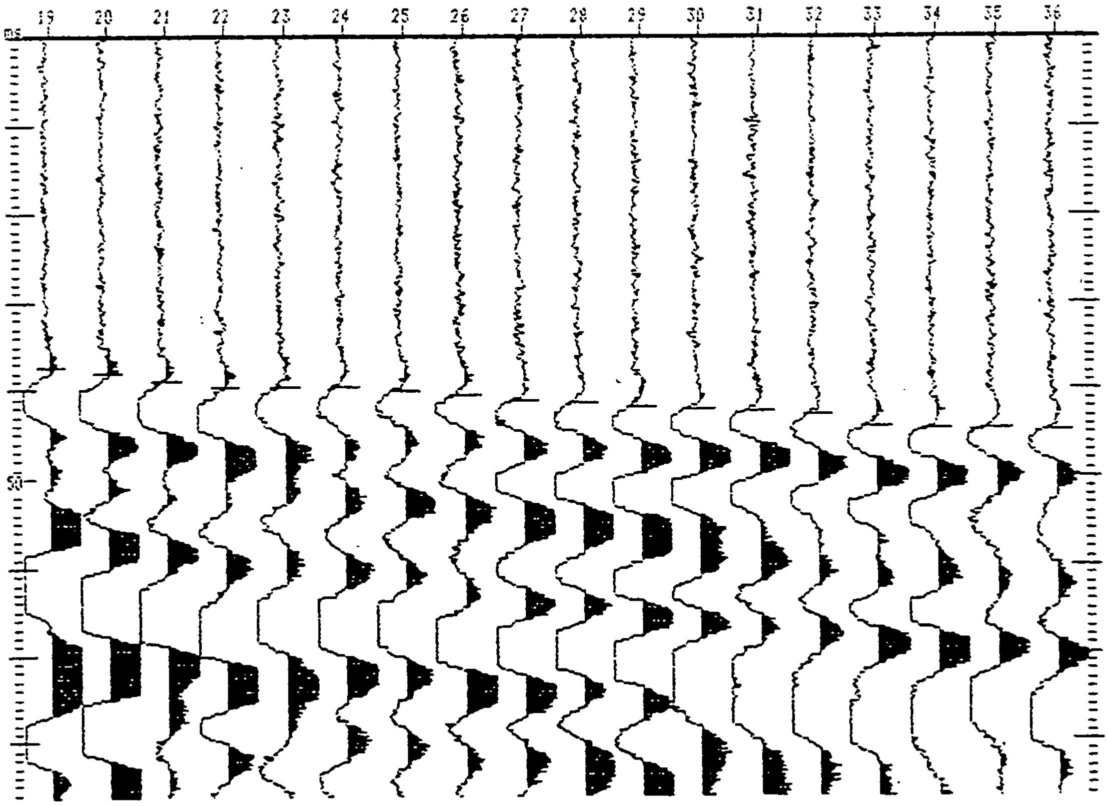
Profile ID:	TAMWA17/23	Method:	Automatic
Project:	BGS	Date:	94/02/28
Customer:	ODA	Created:	11:02
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:1



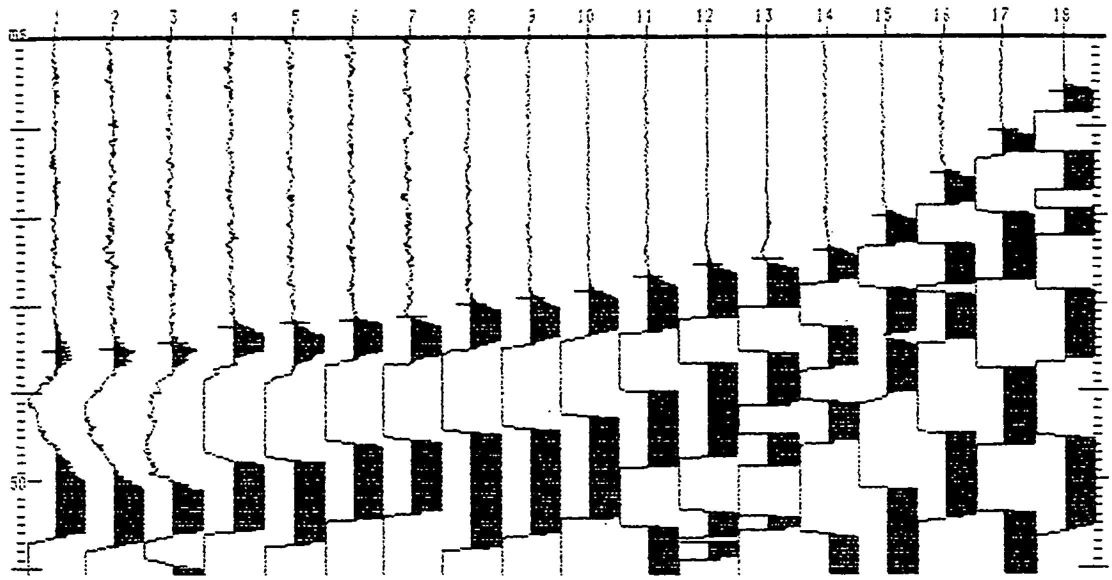
Profile ID:	TAMWA17/23	Method:	Automatic
Project:	BGS	Date:	94/02/28
Customer:	ODA	Created:	11:02
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:1



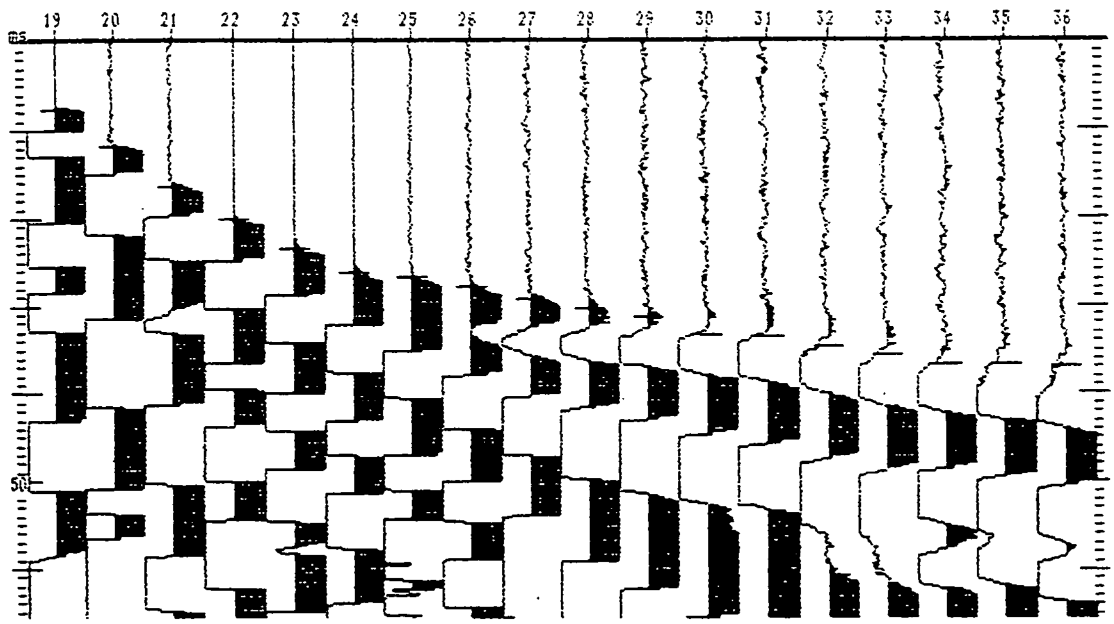
Profile ID:	TAMWA17/23	Method:	Automatic
Project:	BGS	Date:	94/02/28
Customer:	ODA	Created:	11:02
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



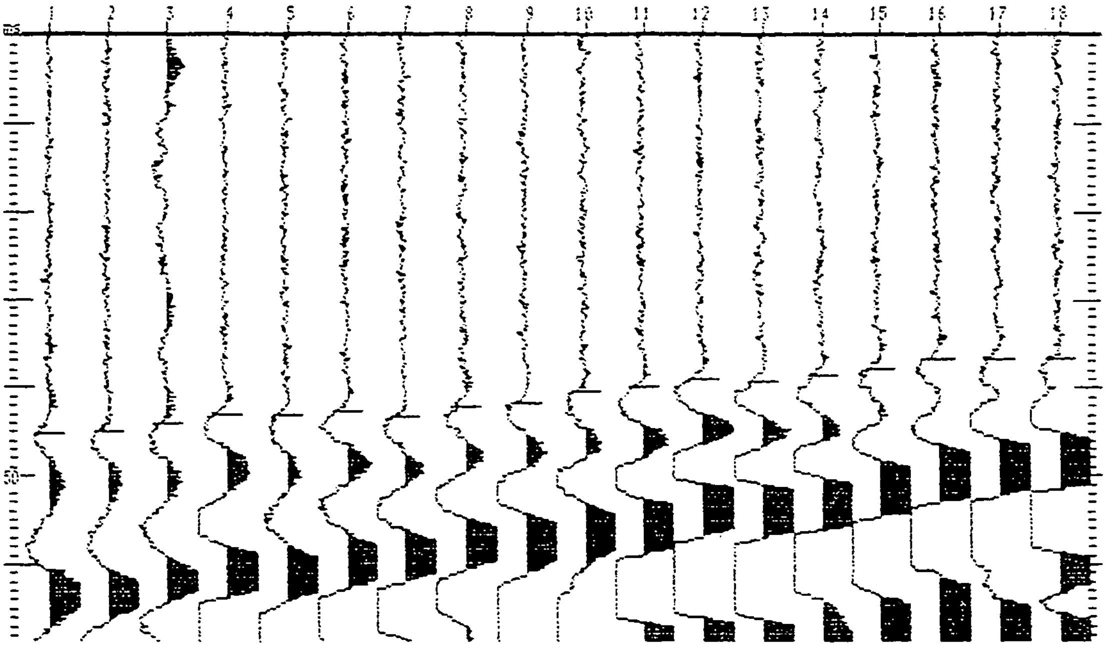
Profile ID:	TAMWA17/23	Method:	Automatic
Project:	BGS	Date:	94/02/28
Customer:	ODA	Created:	11:02
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



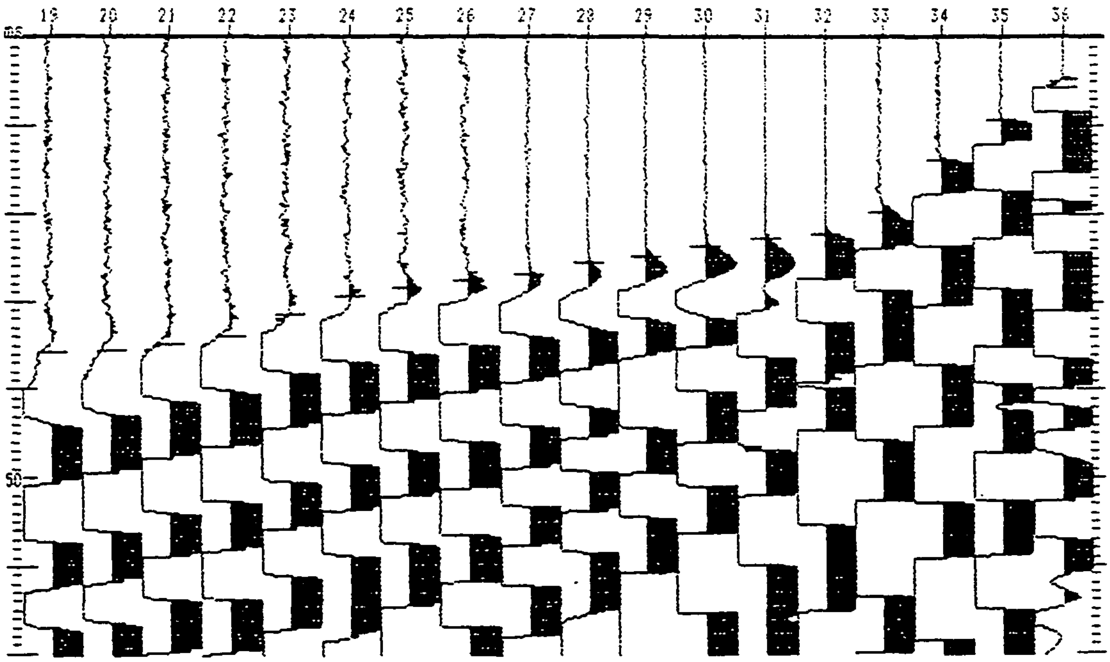
Profile ID:	TAMWA17/23	Method:	Automatic
Project:	BGS	Date:	94/02/28
Customer:	ODA	Created:	11:02
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:3



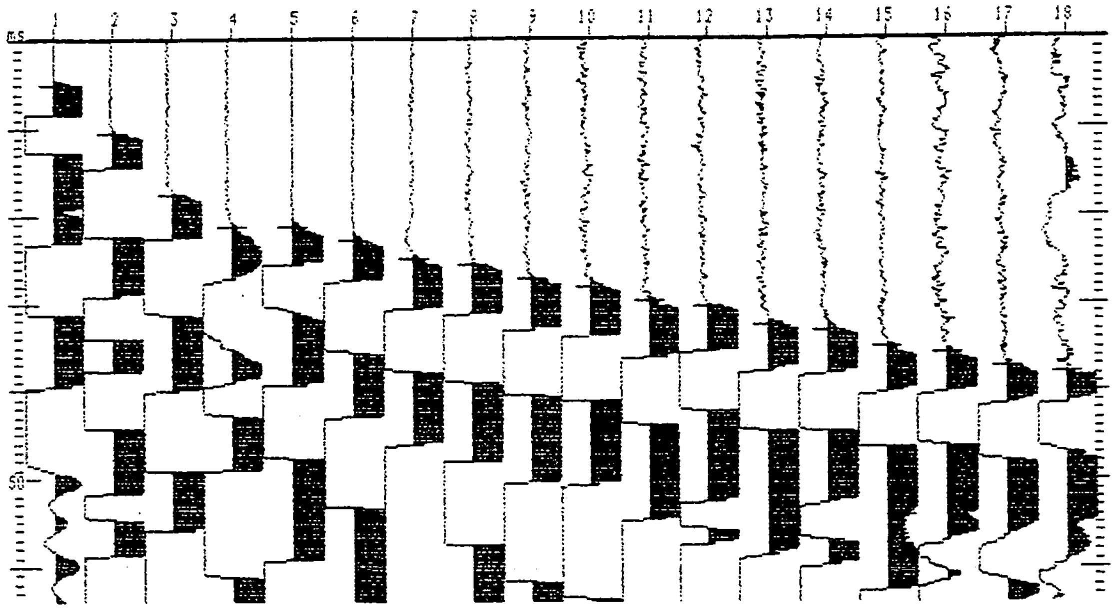
Profile ID:	TAMWA17/23	Method:	Automatic
Project:	BGS	Date:	94/02/28
Customer:	ODA	Created:	11:02
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:3



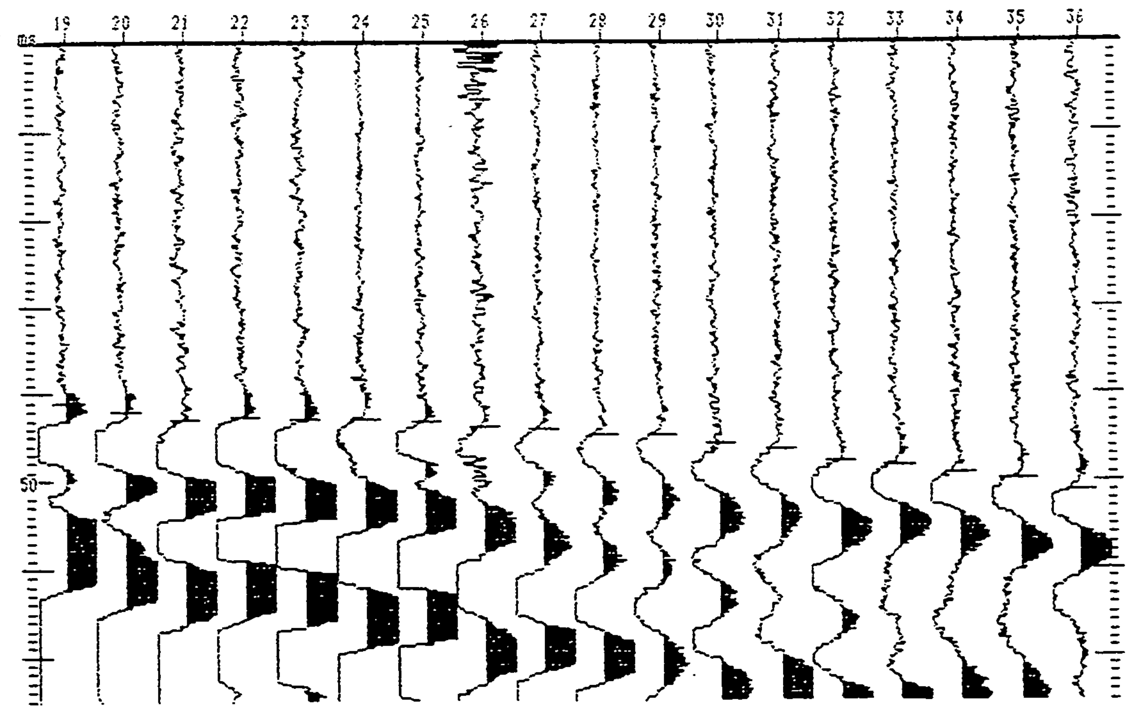
Profile ID:	TAMWA18/20/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/02
Customer:	ODA	Created:	11:28
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:1



Profile ID:	TAMWA18/20/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/02
Customer:	ODA	Created:	11:28
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

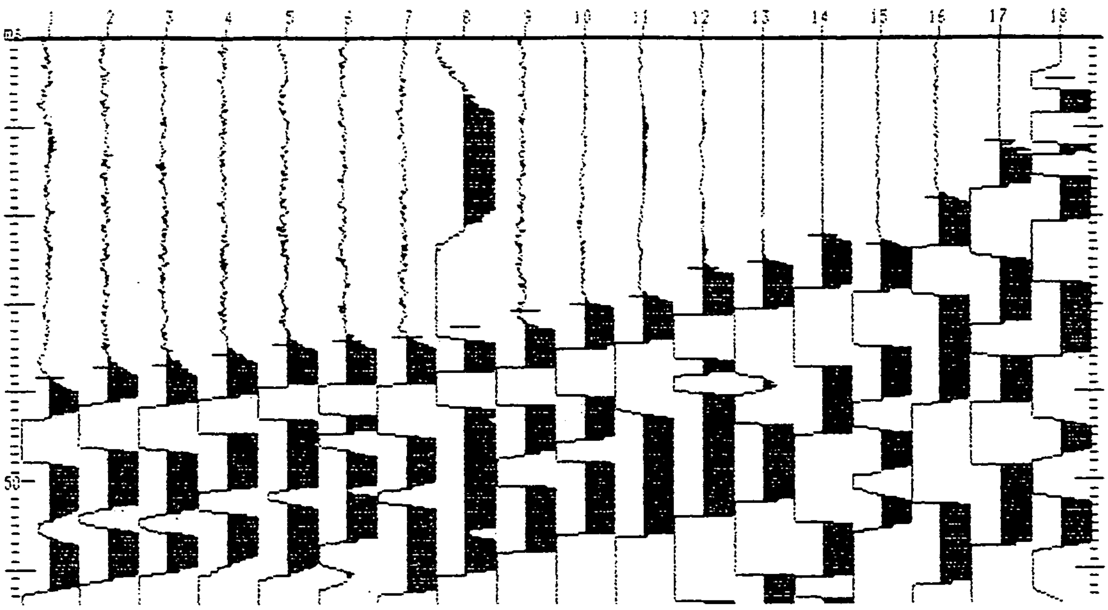
Channel:1



Profile ID: TAMWA18/20/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/02
Created: 11:28
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

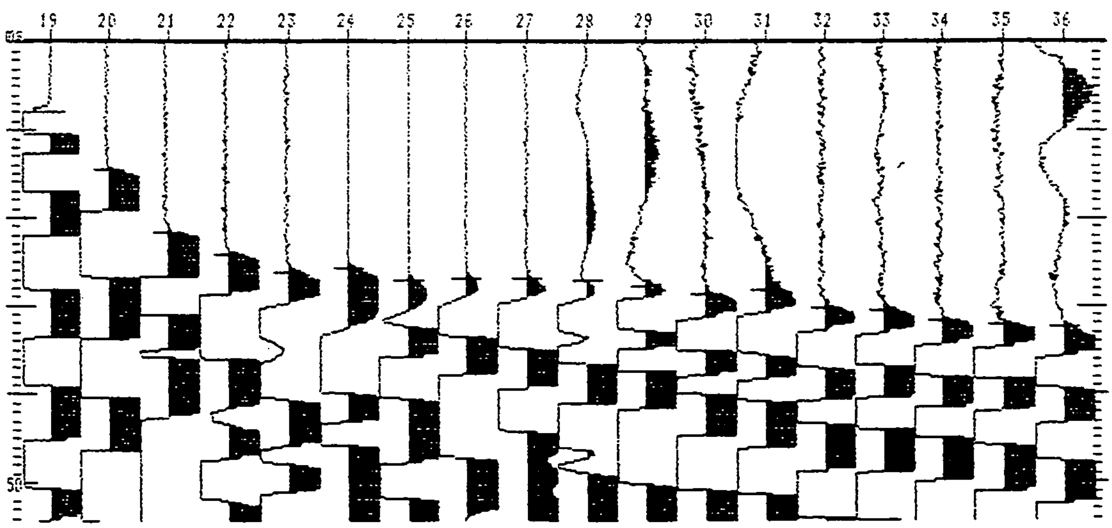
Channel:2



Profile ID: TAMWA18/20/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/02
Created: 11:28
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

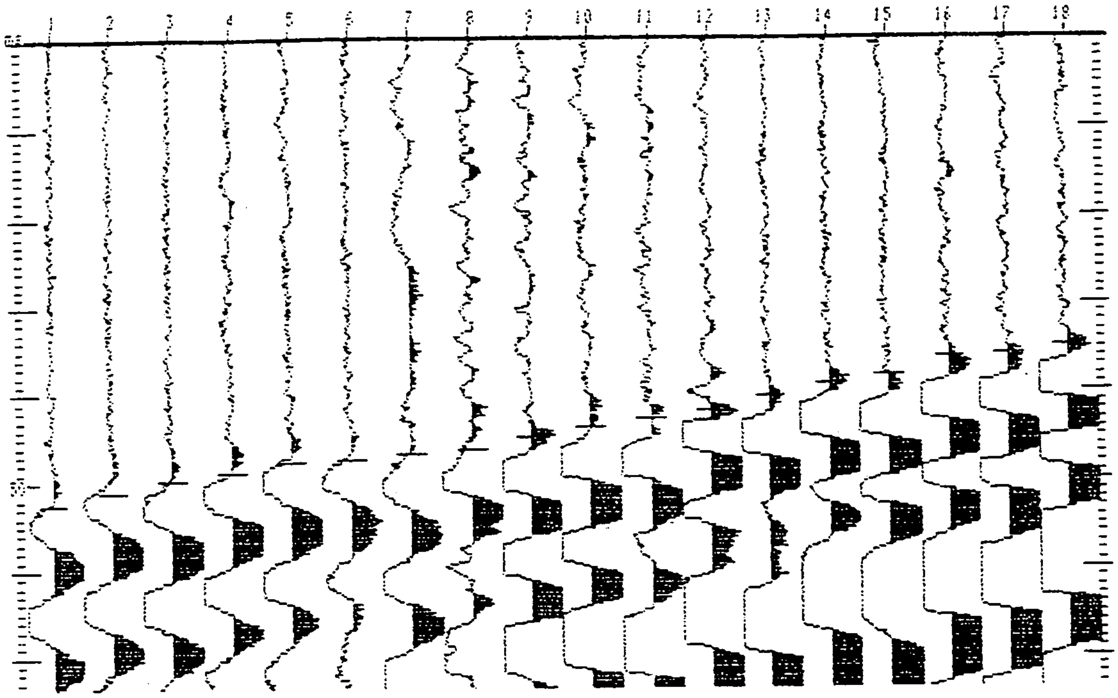
Channel:2



Profile ID: TAMWA18/20/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/02
Created: 11:28
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

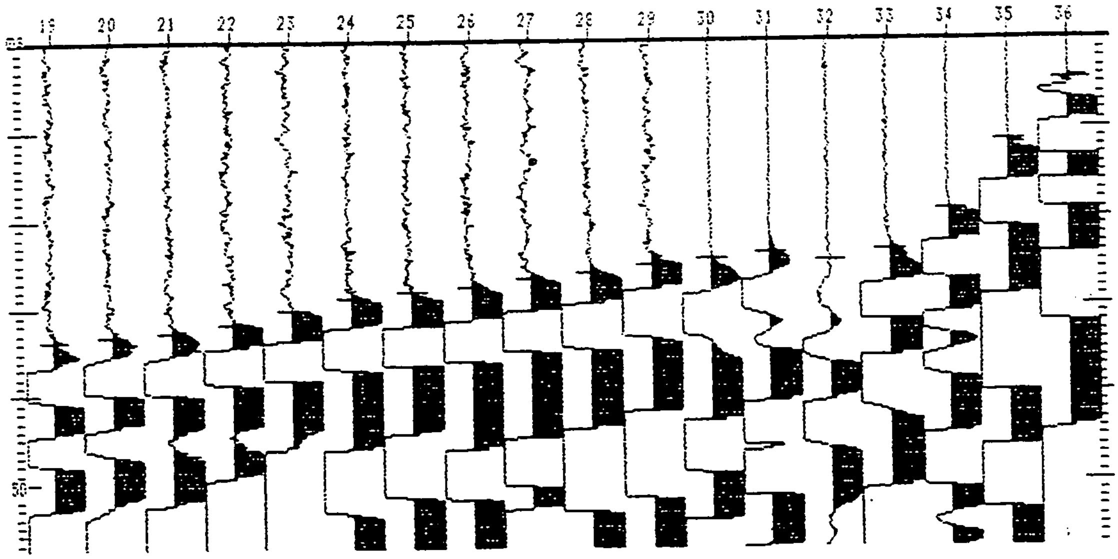
Channel:3



Profile ID: TAMWA18/20/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/02
Created: 11:28
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

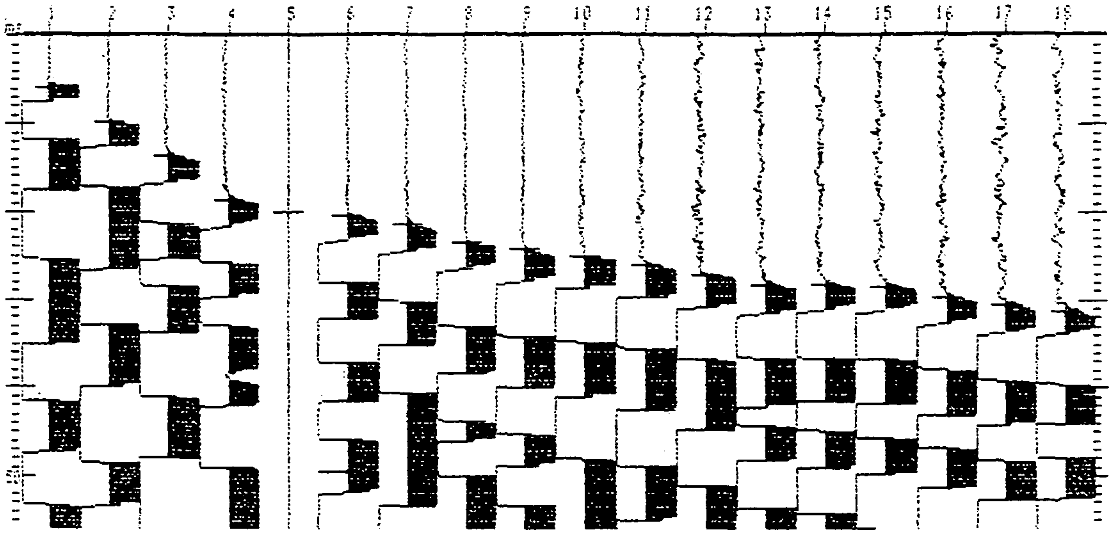
Channel:3



Profile ID: TAMWA19/21/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/02
Created: 13:59
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

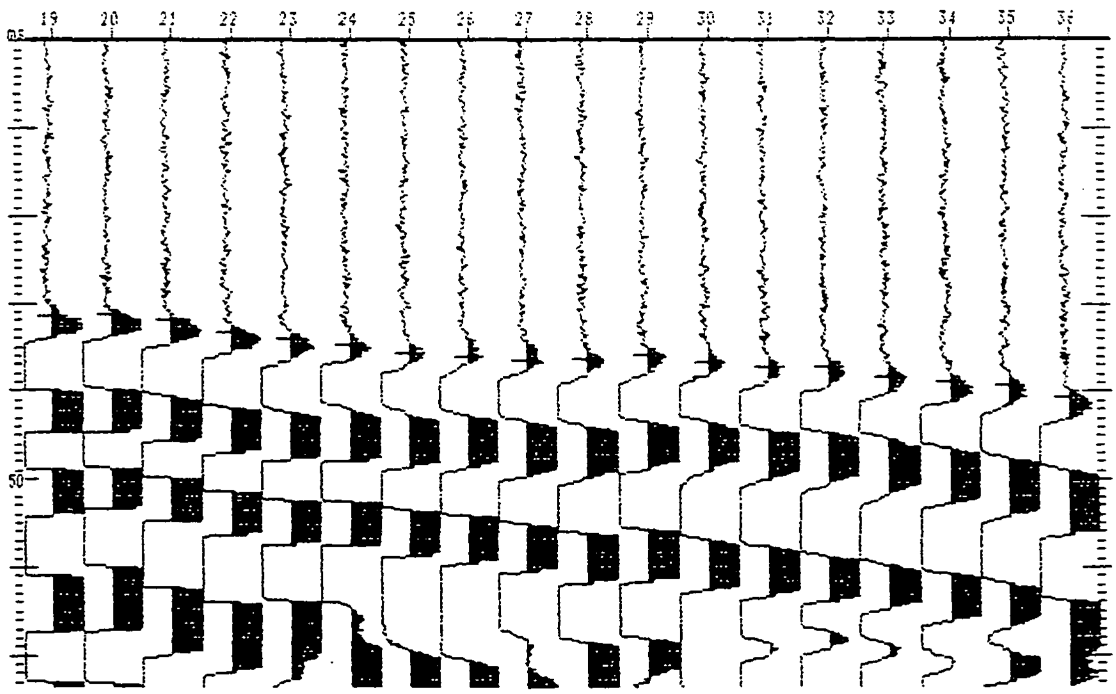
Channel:1



Profile ID: TAMWA19/21/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

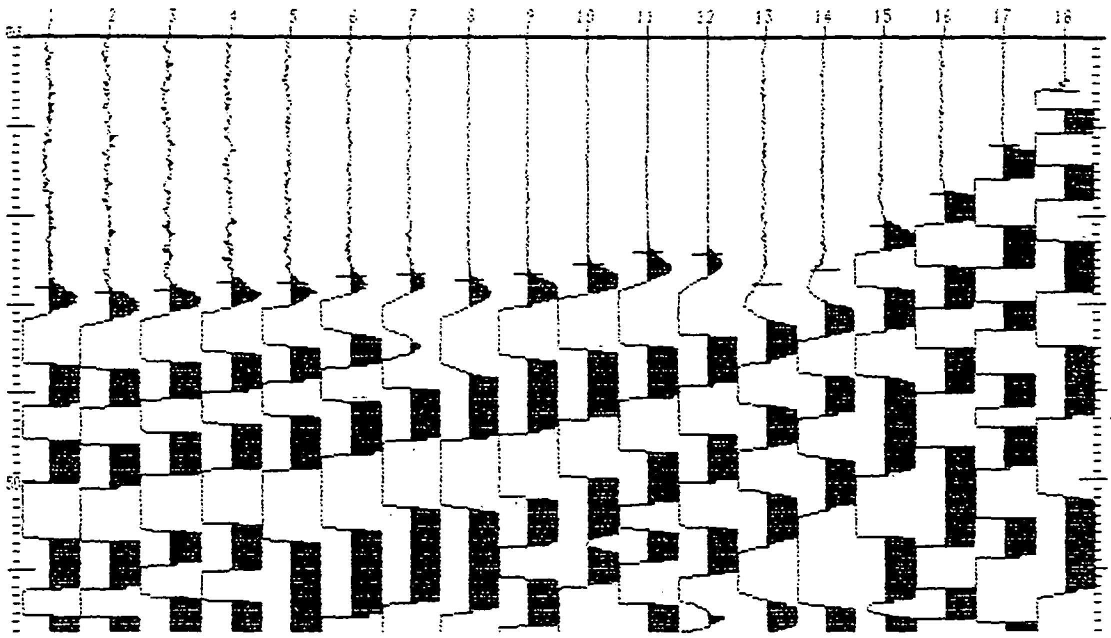
Method: Automatic
Date: 94/03/02
Created: 13:59
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:1



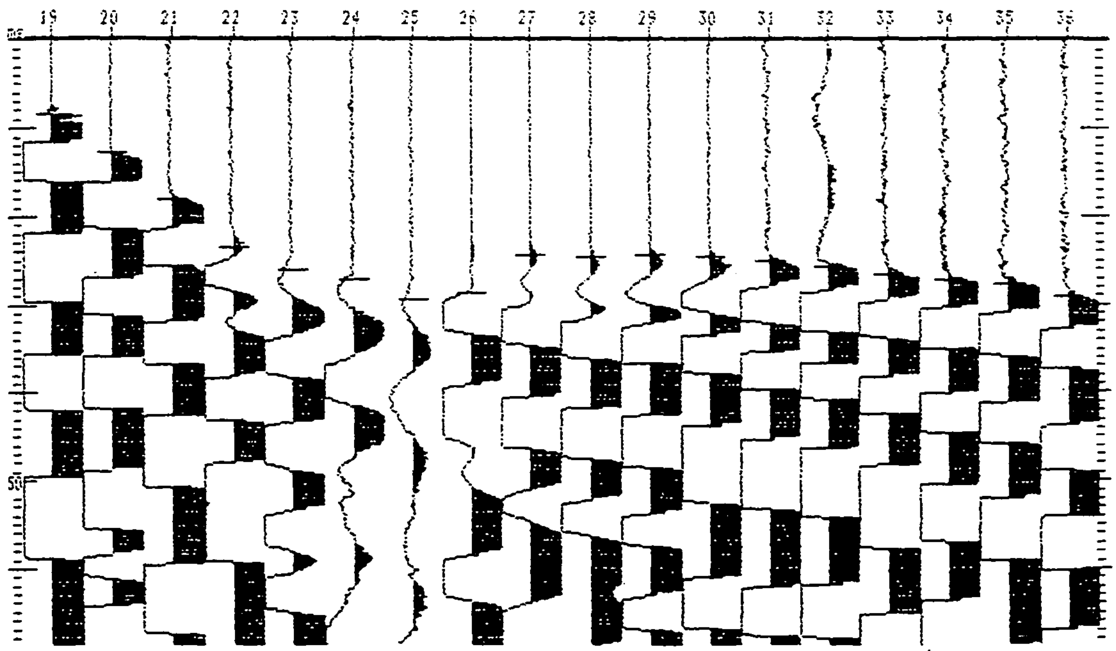
Profile ID:	TAMWA19/21/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/02
Customer:	ODA	Created:	13:59
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



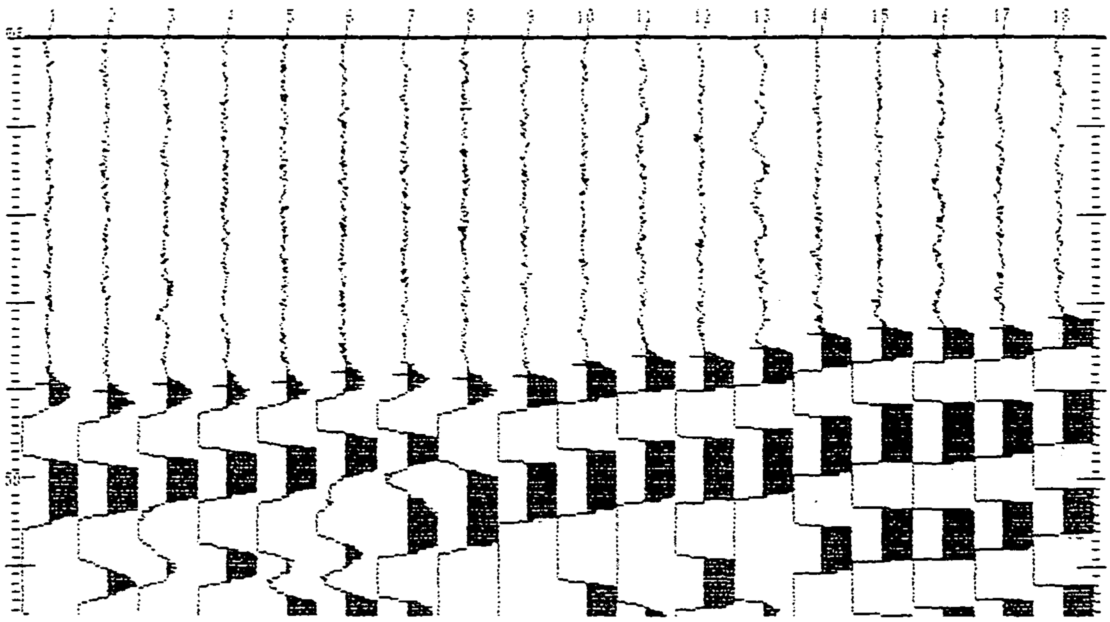
Profile ID:	TAMWA19/21/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/02
Customer:	ODA	Created:	13:59
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



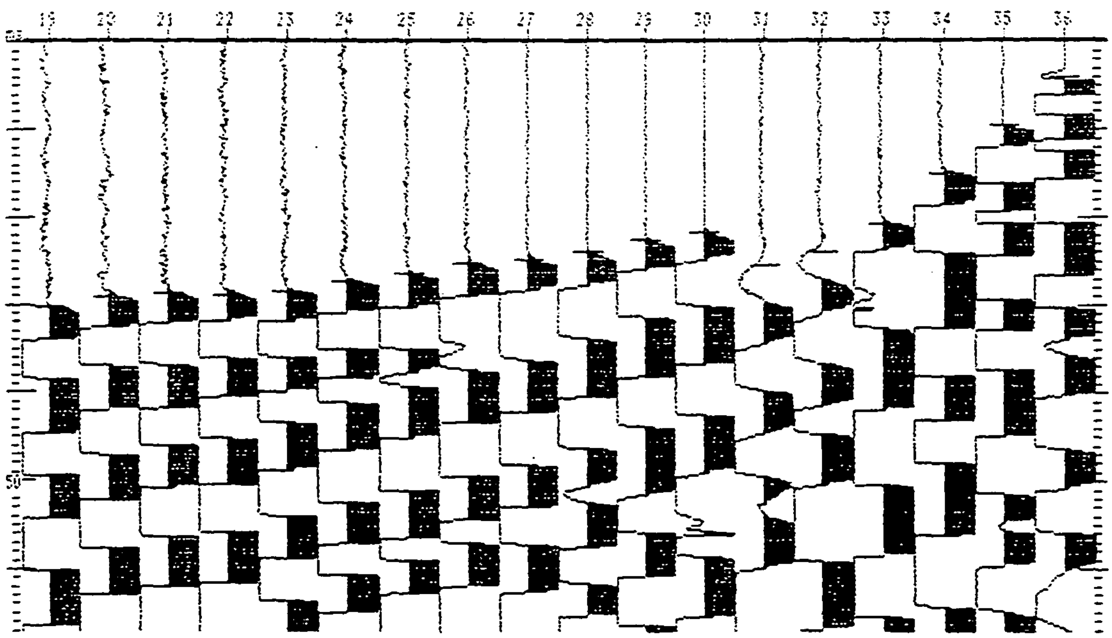
Profile ID:	TAMWA19/21/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/02
Customer:	ODA	Created:	13:59
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:3



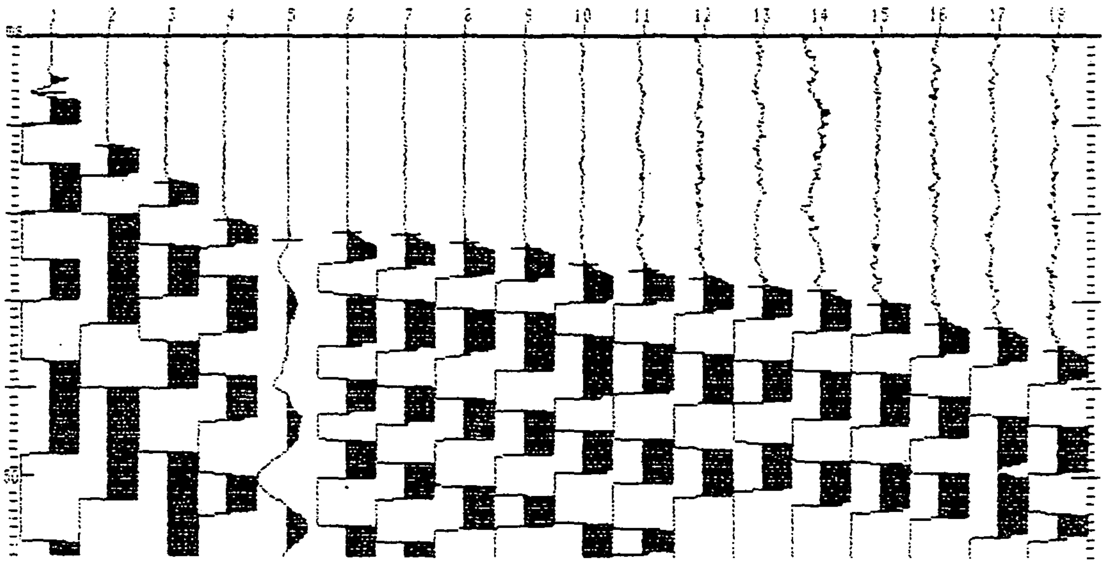
Profile ID:	TAMWA19/21/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/02
Customer:	ODA	Created:	13:59
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:3



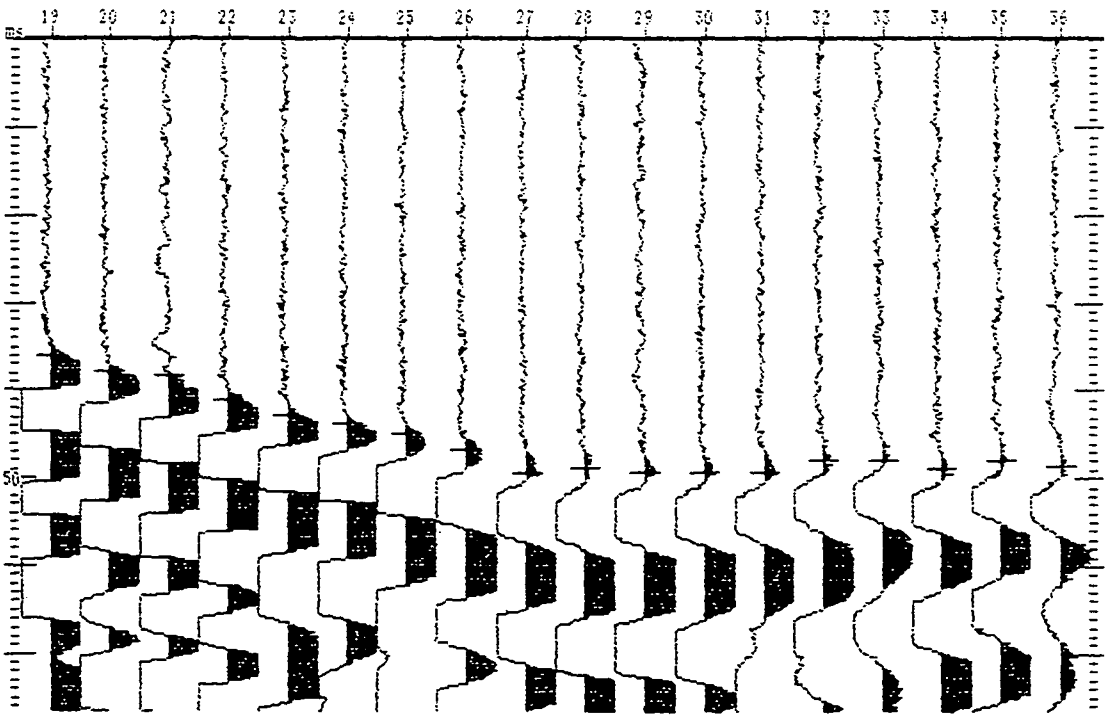
Profile ID:	TAMWA20/K3/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	09:05
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:1



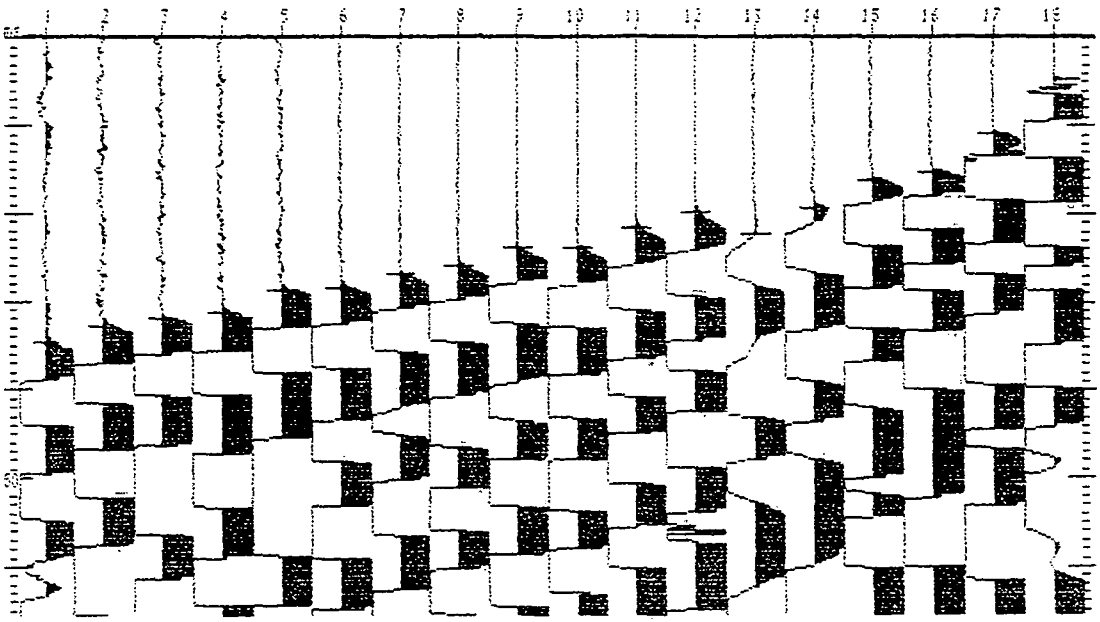
Profile ID:	TAMWA20/K3/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	09:05
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:1



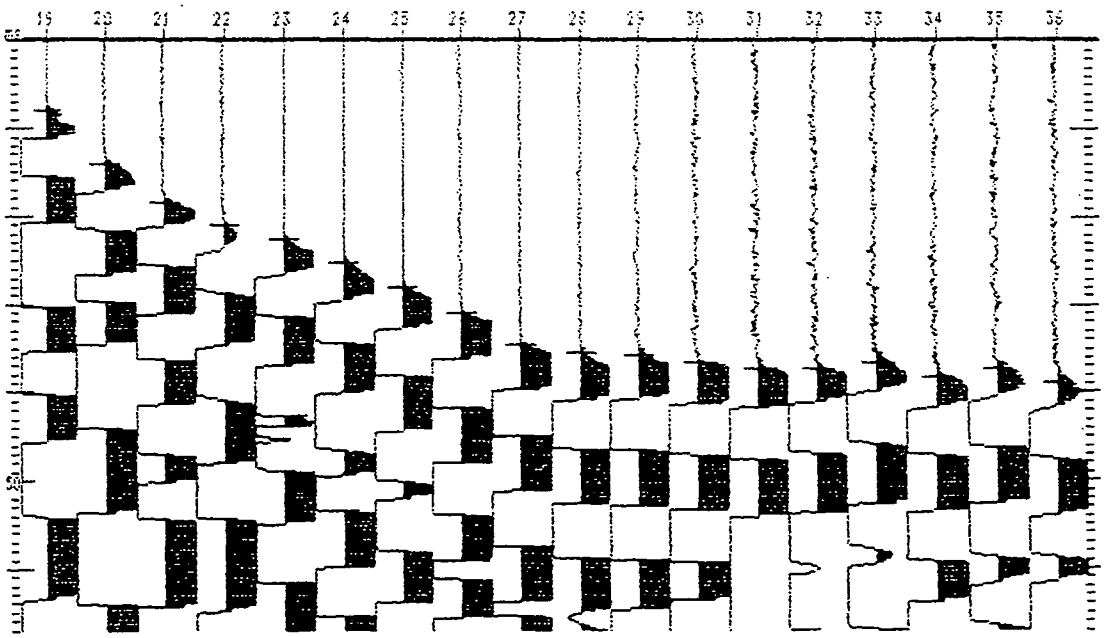
Profile ID:	TAMWA20/K3/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	09:05
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



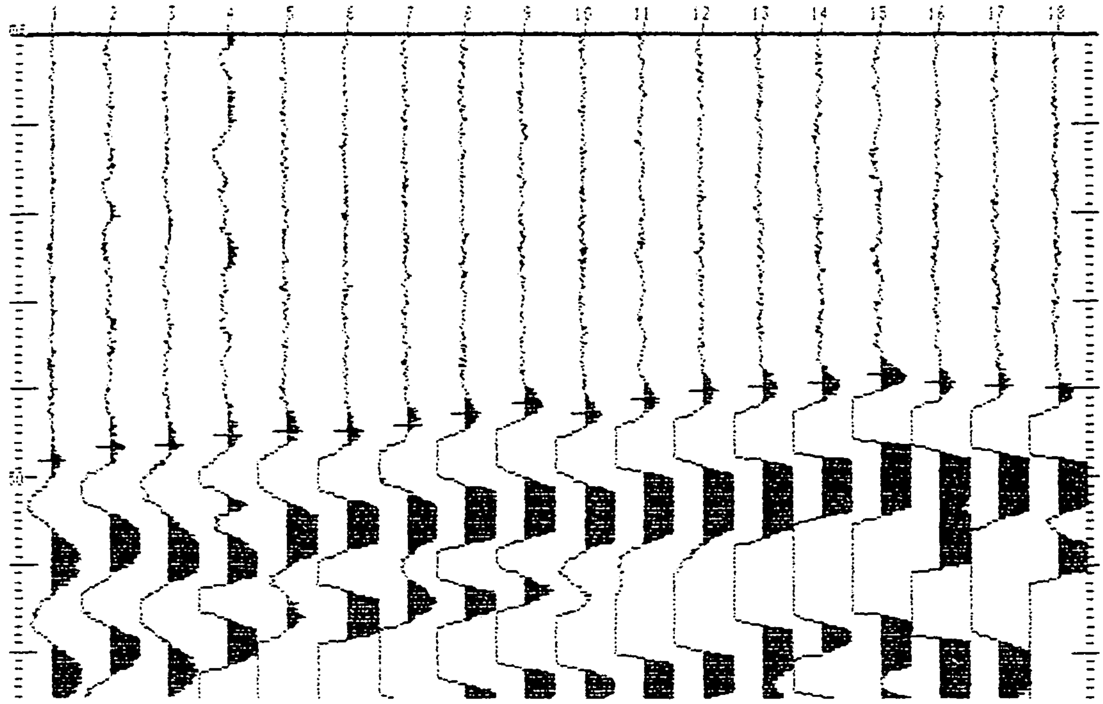
Profile ID:	TAMWA20/K3/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	09:05
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



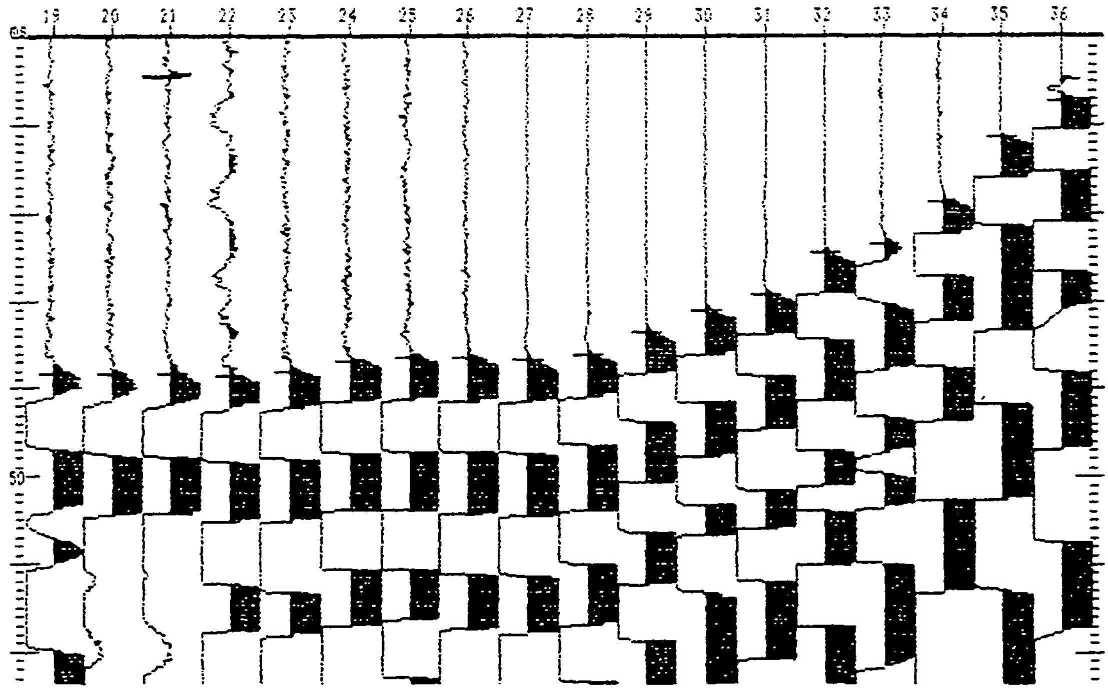
Profile ID:	TAMWA20/K3/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	09:05
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:3



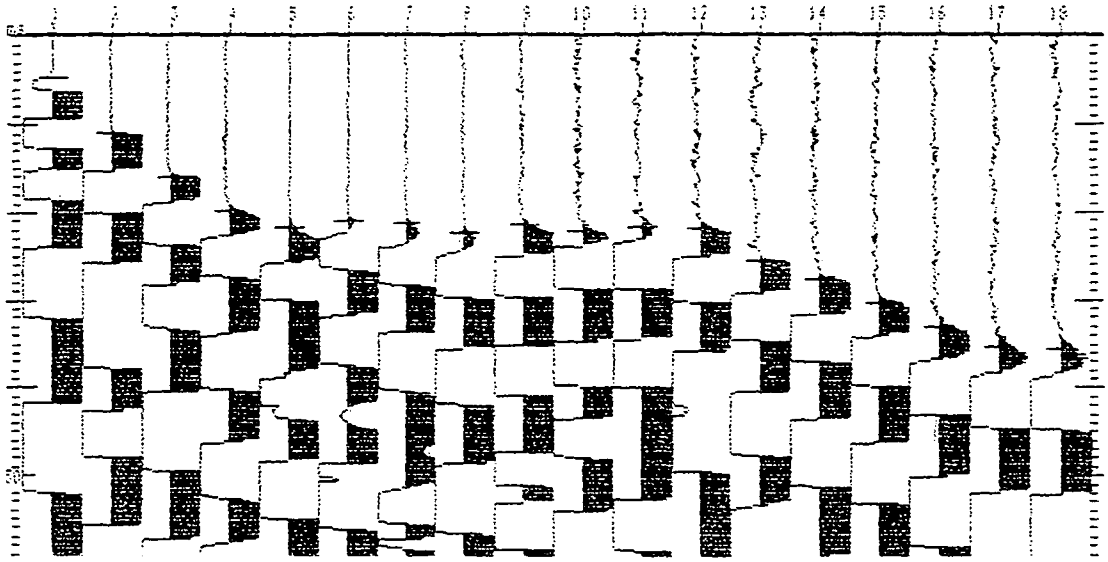
Profile ID:	TAMWA20/K3/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	09:05
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:3



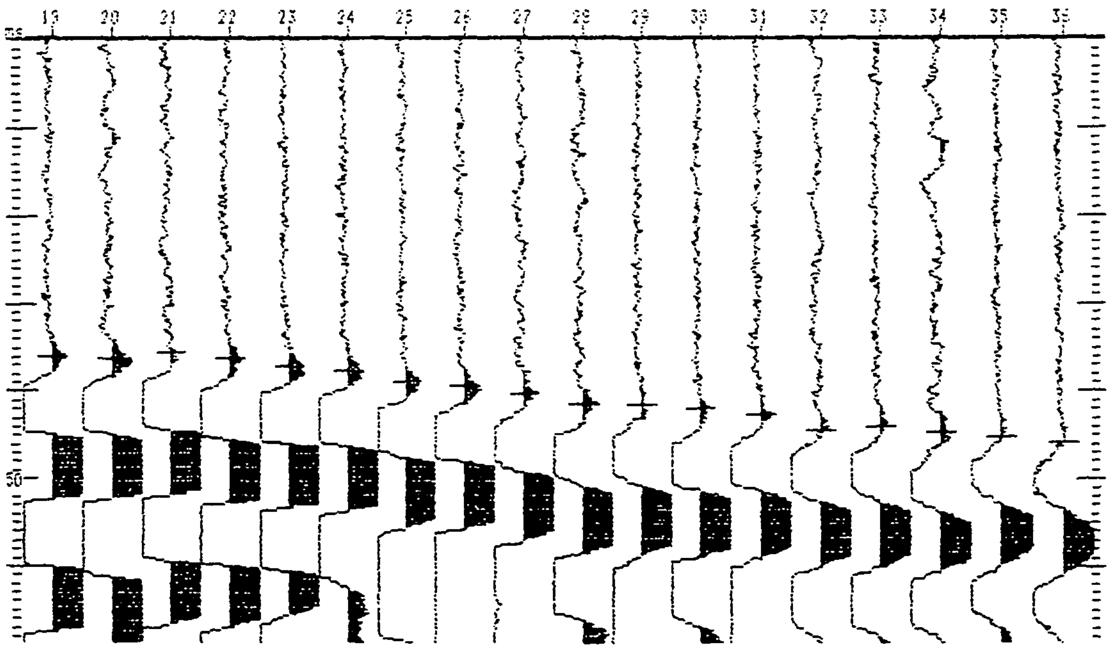
Profile ID: TAMWA21/L1/S-N Method: Automatic
Project: BGS Date: 94/03/03
Customer: ODA Created: 11:18
Cust. ref.: ODA Geoph. spacing: 54.0 m
Operator: JEFF AND PHILL Shot spacing: 3.0 m
Comments: CLOUDY WINDY STEEL PLATE Start offset: 1.5 m

Channel:1



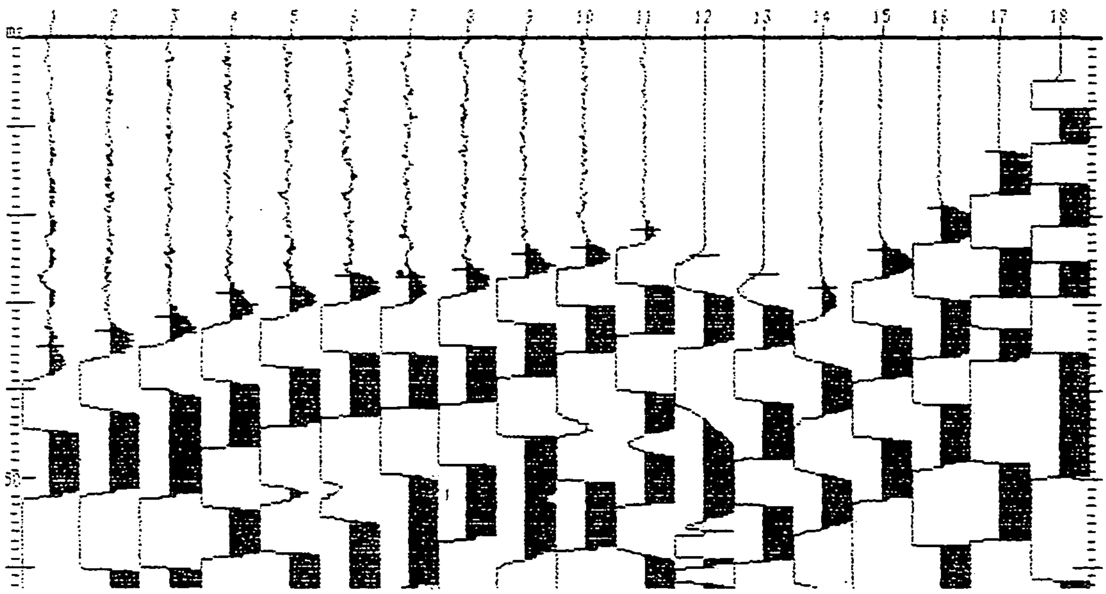
Profile ID: TAMWA21/L1/S-N Method: Automatic
Project: BGS Date: 94/03/03
Customer: ODA Created: 11:18
Cust. ref.: ODA Geoph. spacing: 54.0 m
Operator: JEFF AND PHILL Shot spacing: 3.0 m
Comments: CLOUDY WINDY STEEL PLATE Start offset: 1.5 m

Channel:1



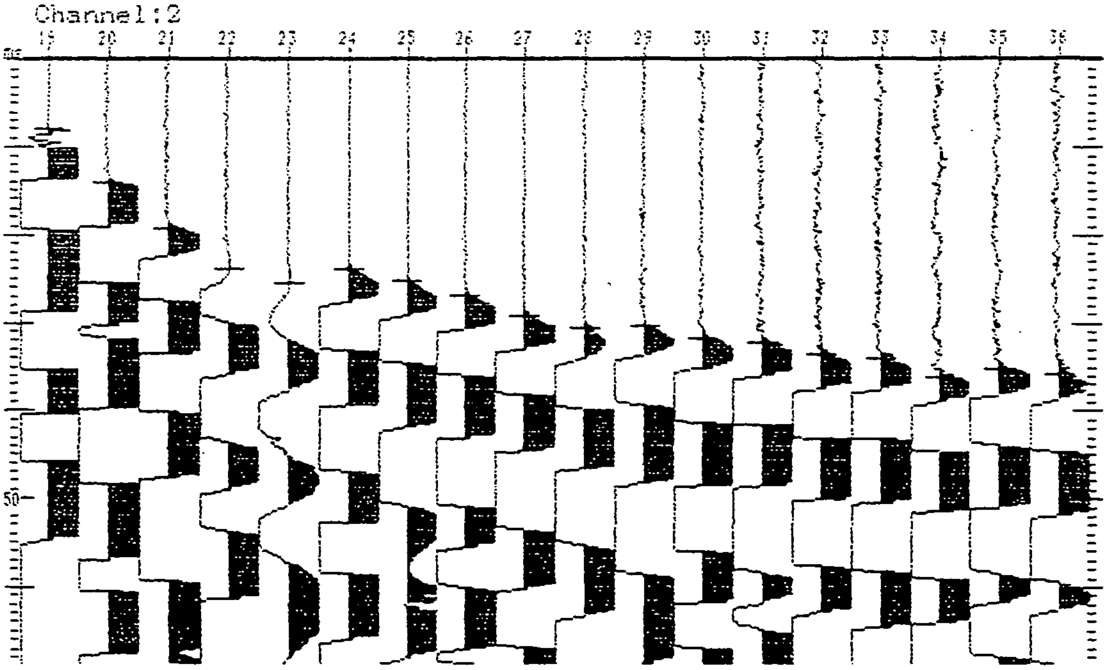
Profile ID:	TAMWA21/L1/S-N	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	11:18
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



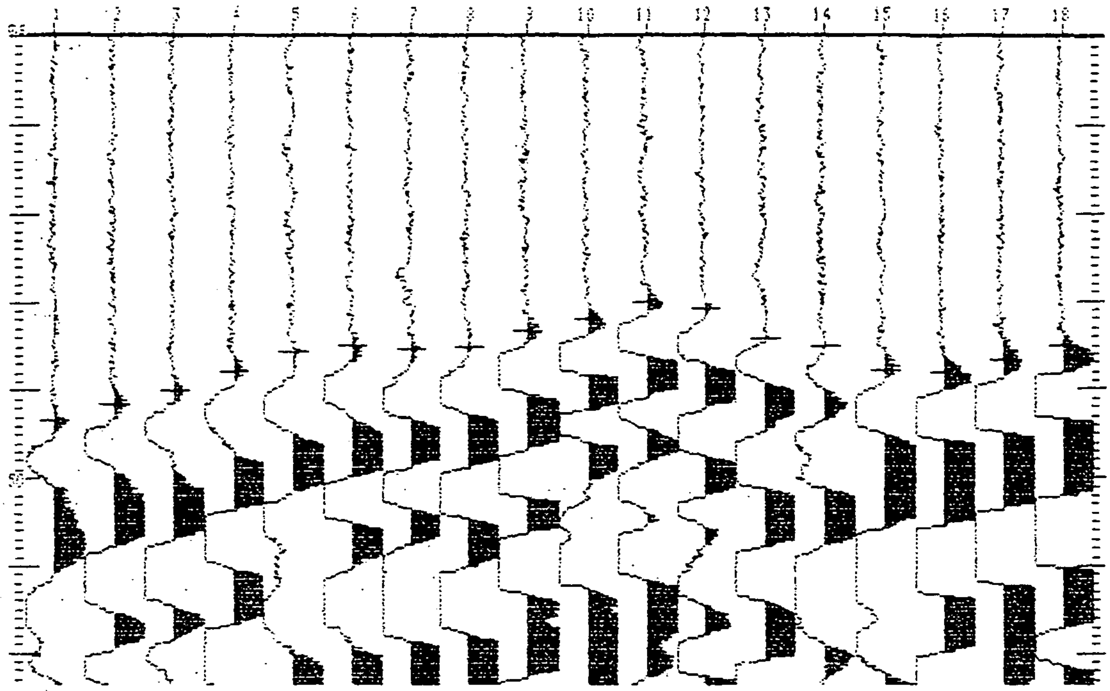
Profile ID:	TAMWA21/L1/S-N	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	11:18
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:2



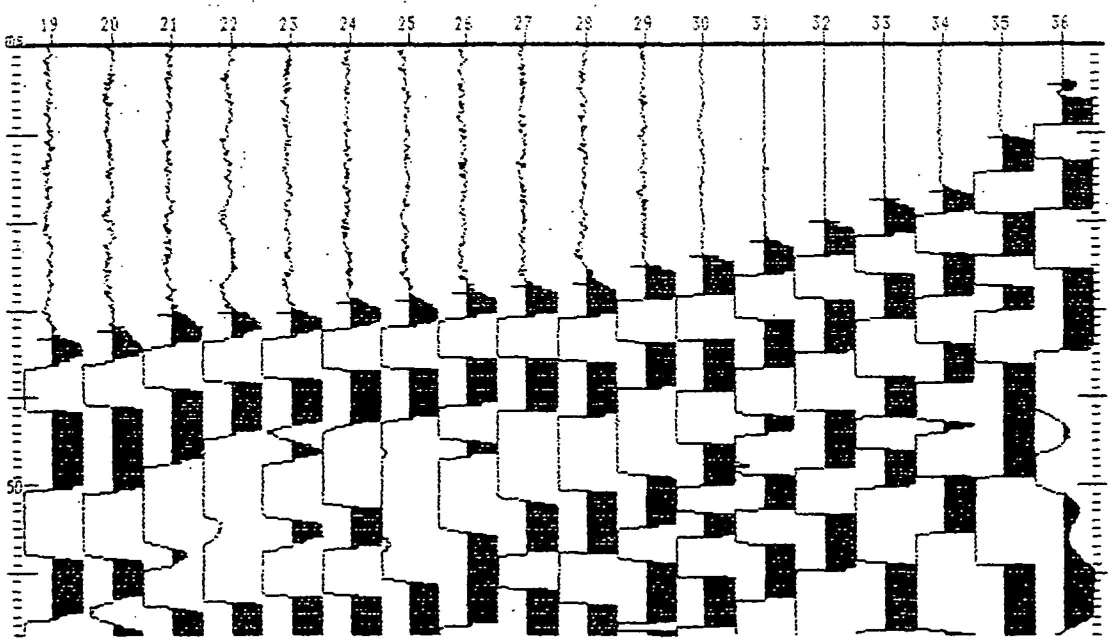
Profile ID:	TAMWA21/L1/S-N	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	11:18
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:3



Profile ID:	TAMWA21/L1/S-N	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	11:18
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

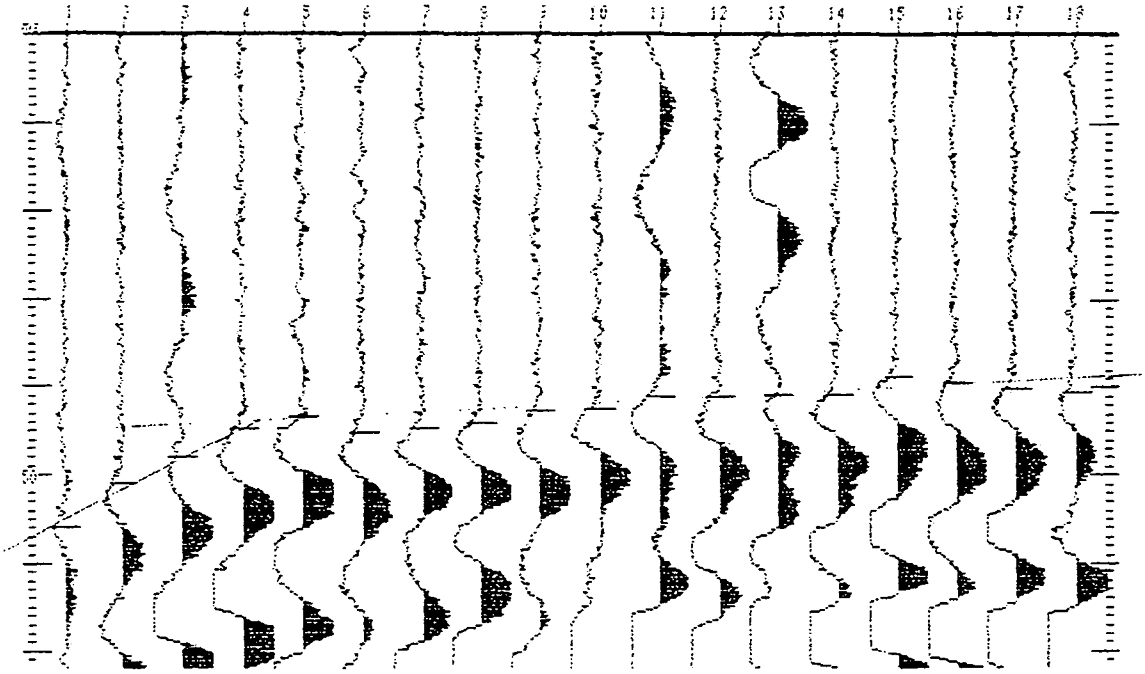
Channel:3



Profile ID: TAMWA22/US/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/03
Created: 13:08
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

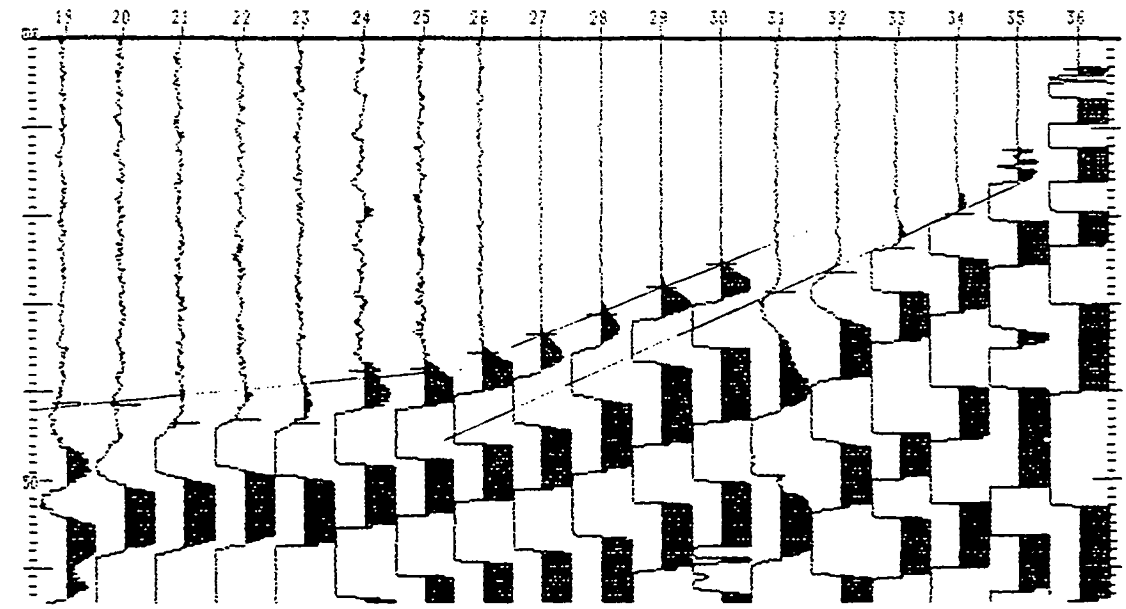
Channel:3



Profile ID: TAMWA22/US/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

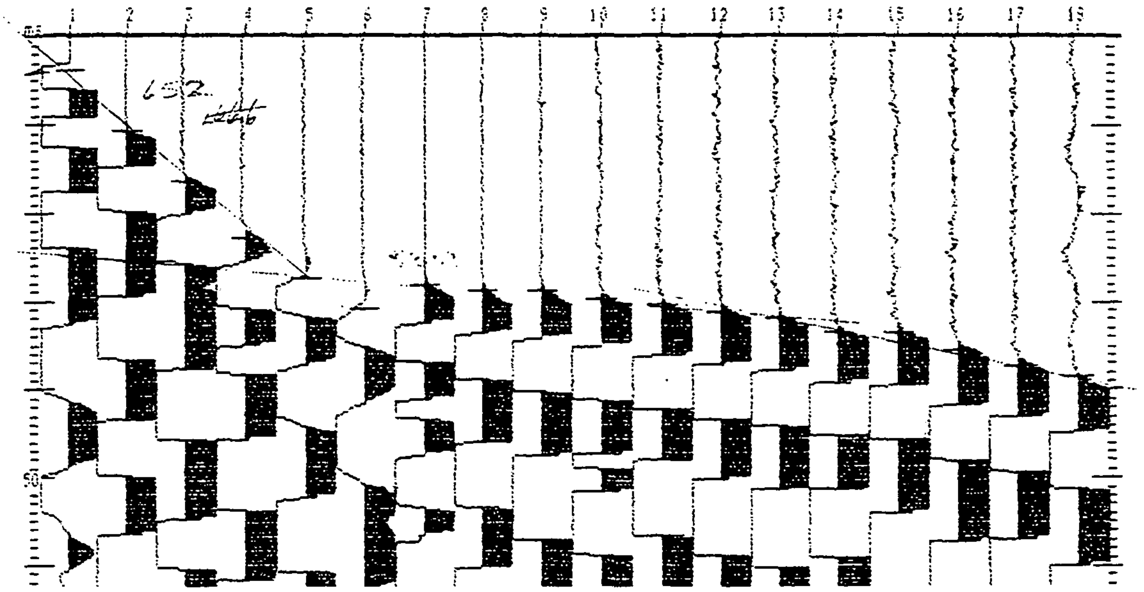
Method: Automatic
Date: 94/03/03
Created: 13:08
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:3



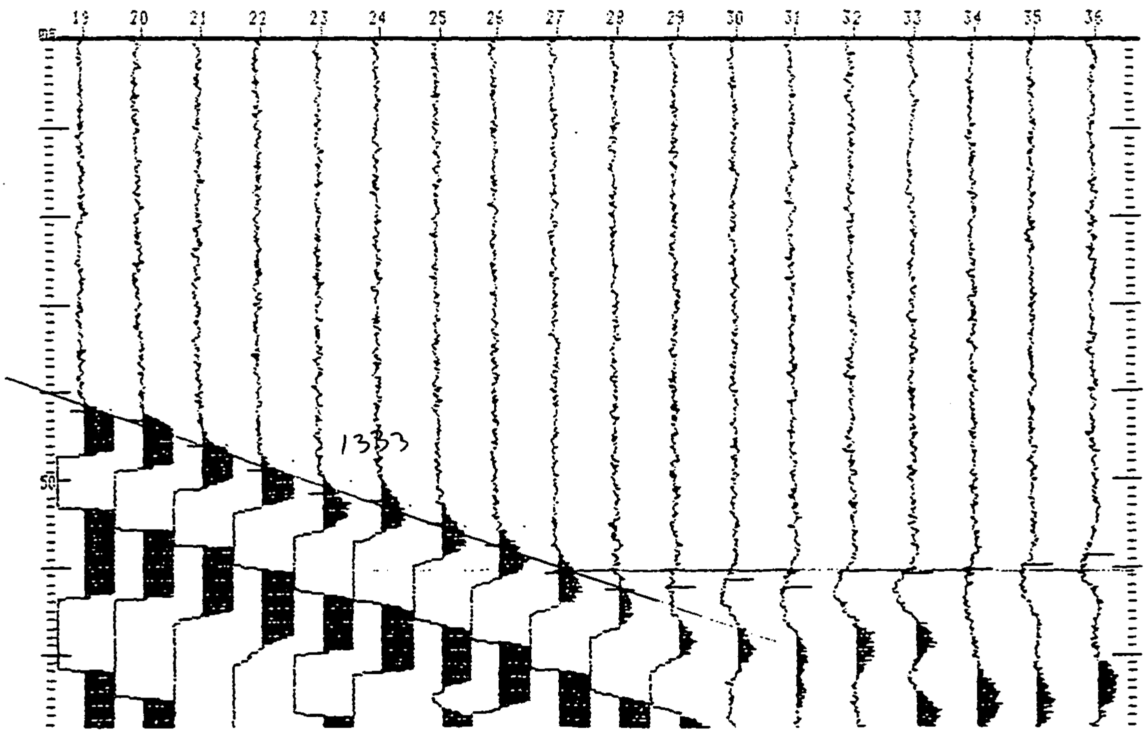
Profile ID:	TAMWA22/U8/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	13:06
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

Channel:1



Profile ID:	TAMWA22/U8/E-W	Method:	Automatic
Project:	BGS	Date:	94/03/03
Customer:	ODA	Created:	13:06
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF AND PHILL	Shot spacing:	3.0 m
Comments:	CLOUDY WINDY STEEL PLATE	Start offset:	1.5 m

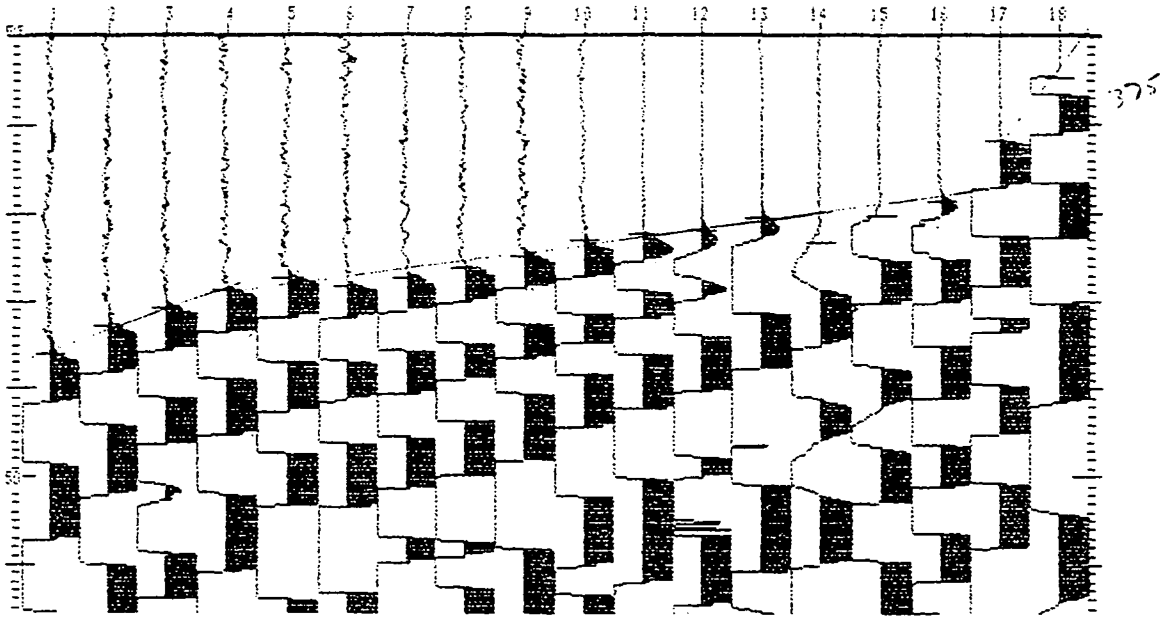
Channel:1



Profile ID: TAMWA22/U8/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/03
Created: 13:08
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

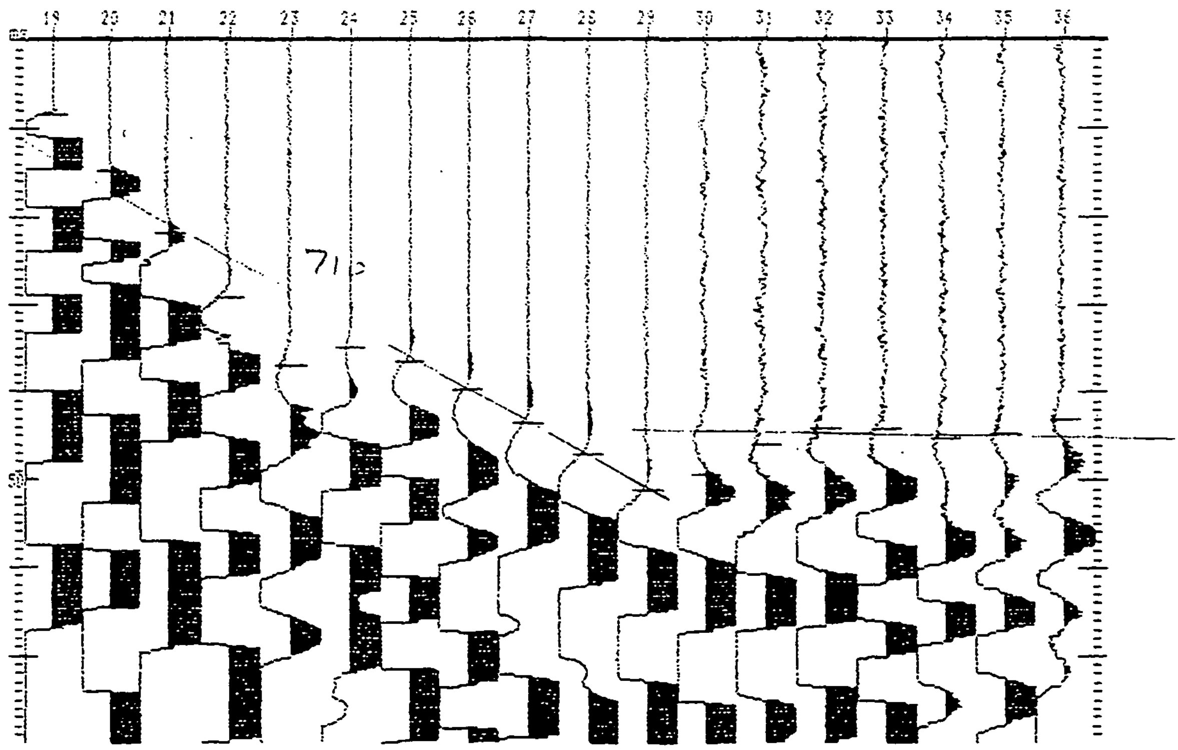
Channel:2



Profile ID: TAMWA22/U8/E-W
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF AND PHILL
Comments: CLOUDY WINDY STEEL PLATE

Method: Automatic
Date: 94/03/03
Created: 13:08
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

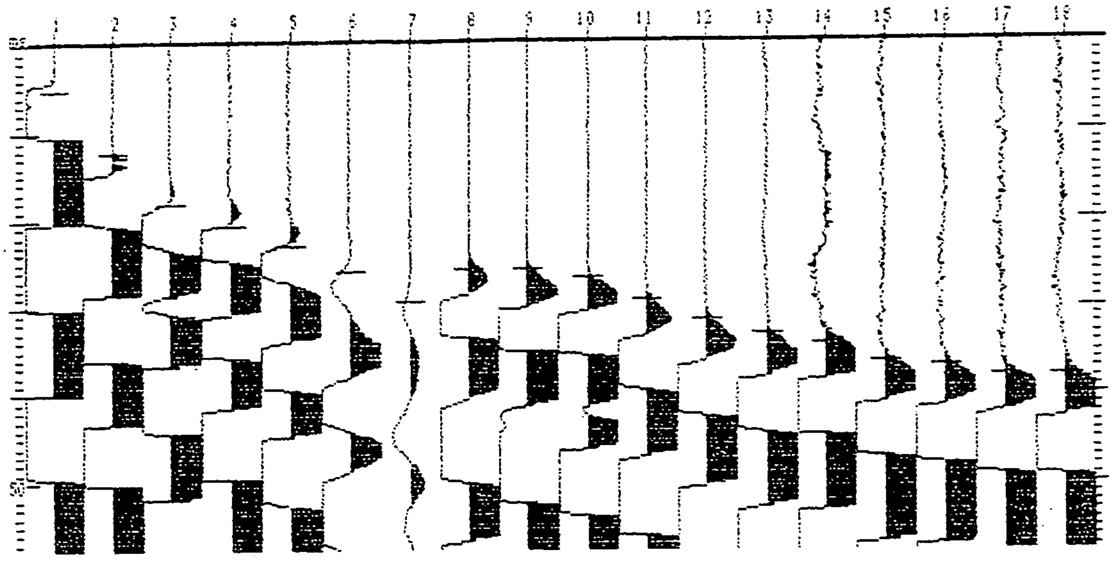
Channel:2



Profile ID: CHIREDZI1/CWWE
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF L
Comments: CLEAR CALM HOT WEIGHT E

Method: Automatic
Date: 94/03/10
Created: 08:29
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

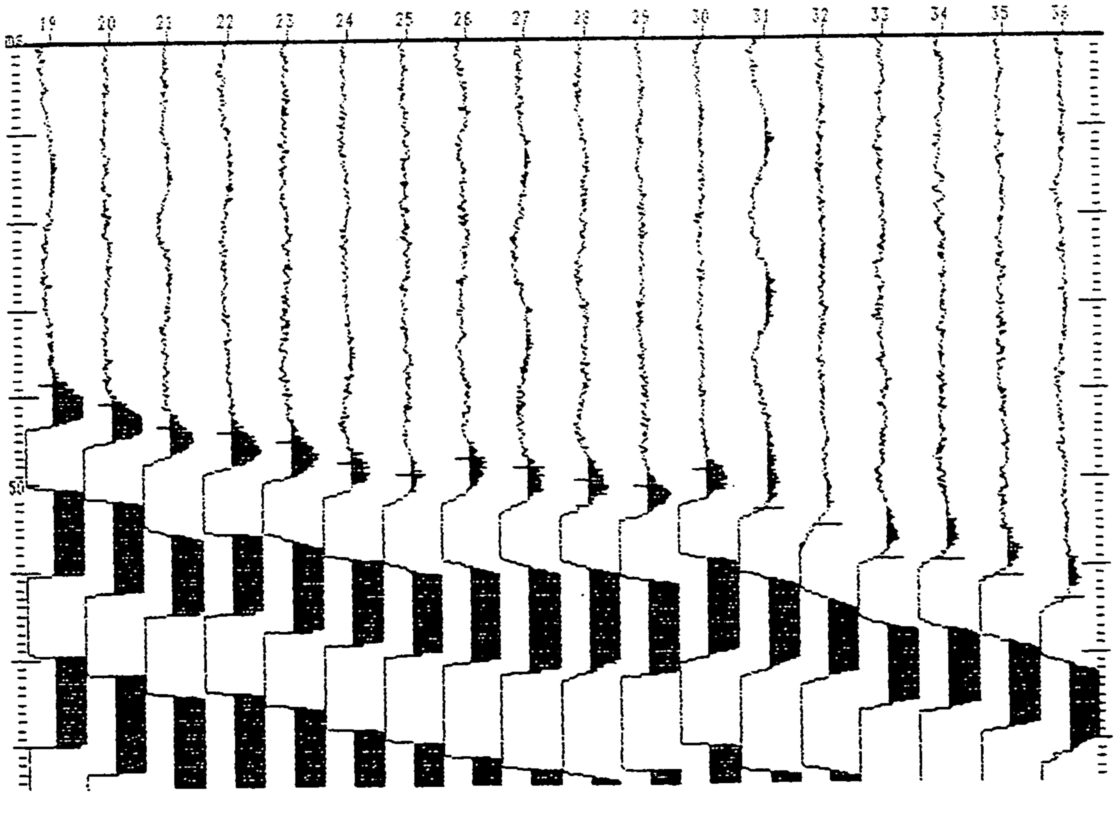
Channel:1



Profile ID: CHIREDZI1/CWWE
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF L
Comments: CLEAR CALM HOT WEIGHT E

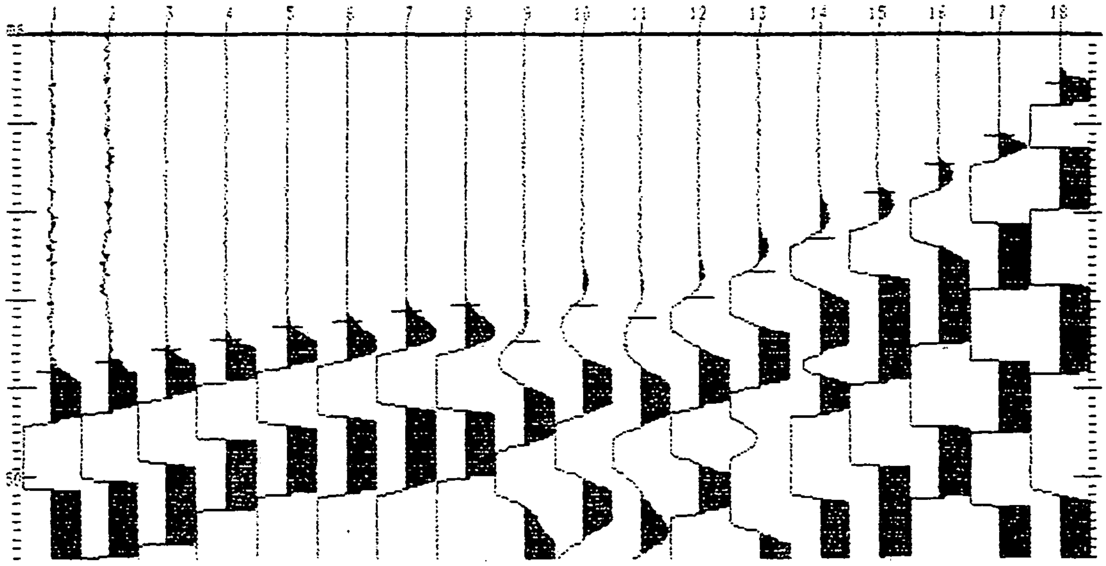
Method: Automatic
Date: 94/03/10
Created: 08:29
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:1



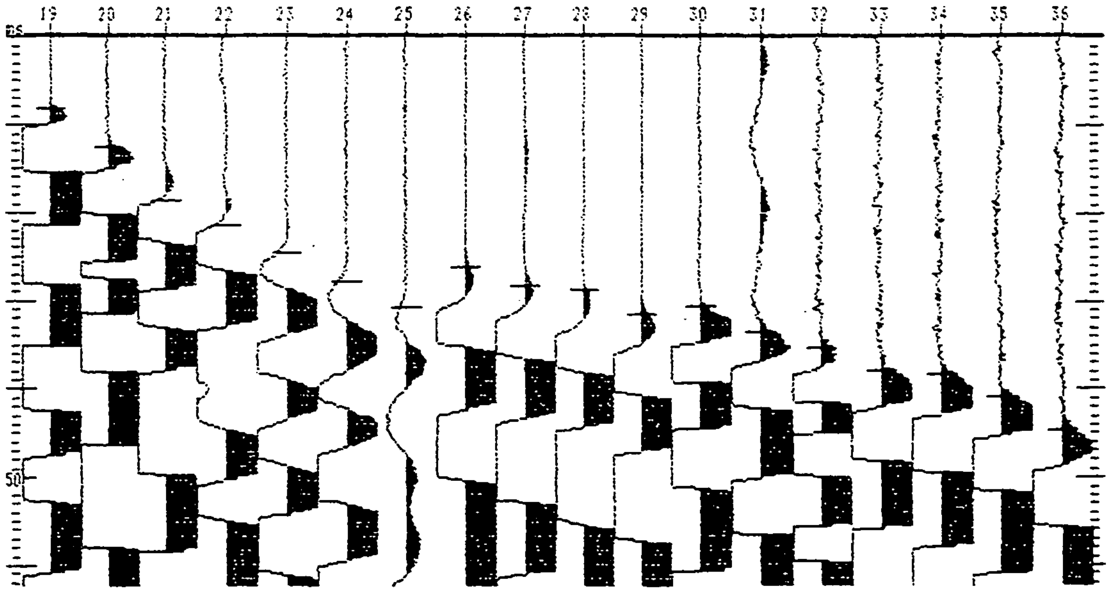
Profile ID:	CHIREDZI1/CWWE	Method:	Automatic
Project:	BGS	Date:	94/03/10
Customer:	ODA	Created:	08:29
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF L	Shot spacing:	3.0 m
Comments:	CLEAR CALM HOT WEIGHT E	Start offset:	1.5 m

Channel:2



Profile ID:	CHIREDZI1/CWWE	Method:	Automatic
Project:	BGS	Date:	94/03/10
Customer:	ODA	Created:	08:29
Cust. ref.:	ODA	Geoph. spacing:	54.0 m
Operator:	JEFF L	Shot spacing:	3.0 m
Comments:	CLEAR CALM HOT WEIGHT E	Start offset:	1.5 m

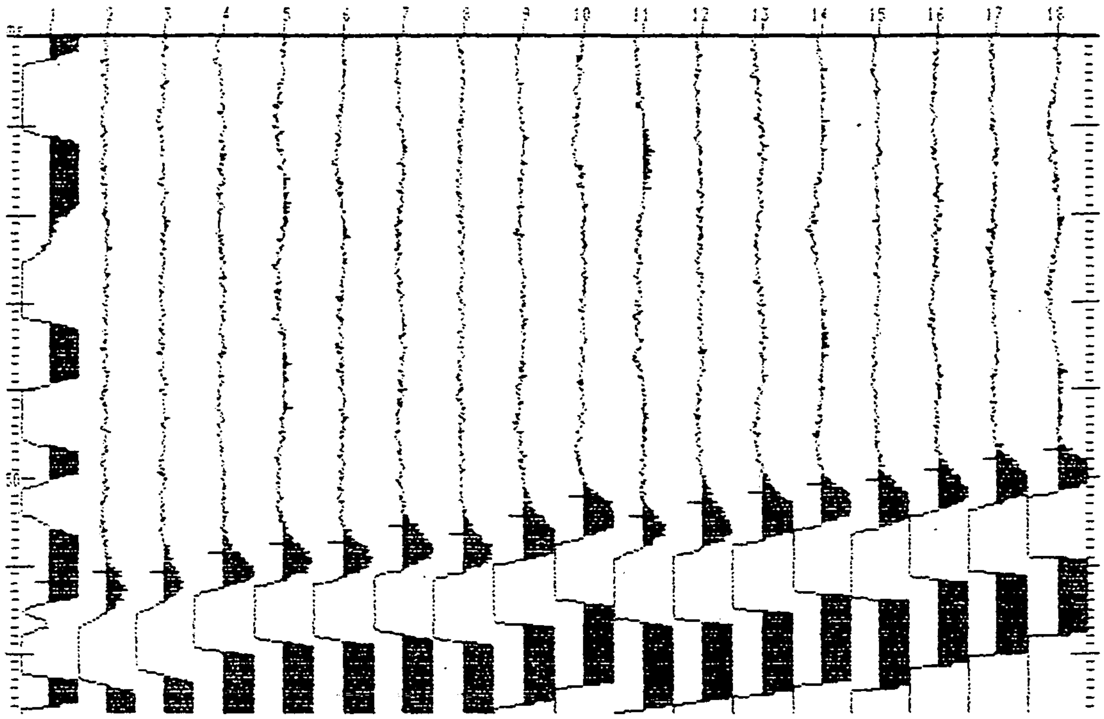
Channel:2



Profile ID: CHIREDZI1/CWWE
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF L
Comments: CLEAR CALM HOT WEIGHT E

Method: Automatic
Date: 94/03/10
Created: 08:29
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

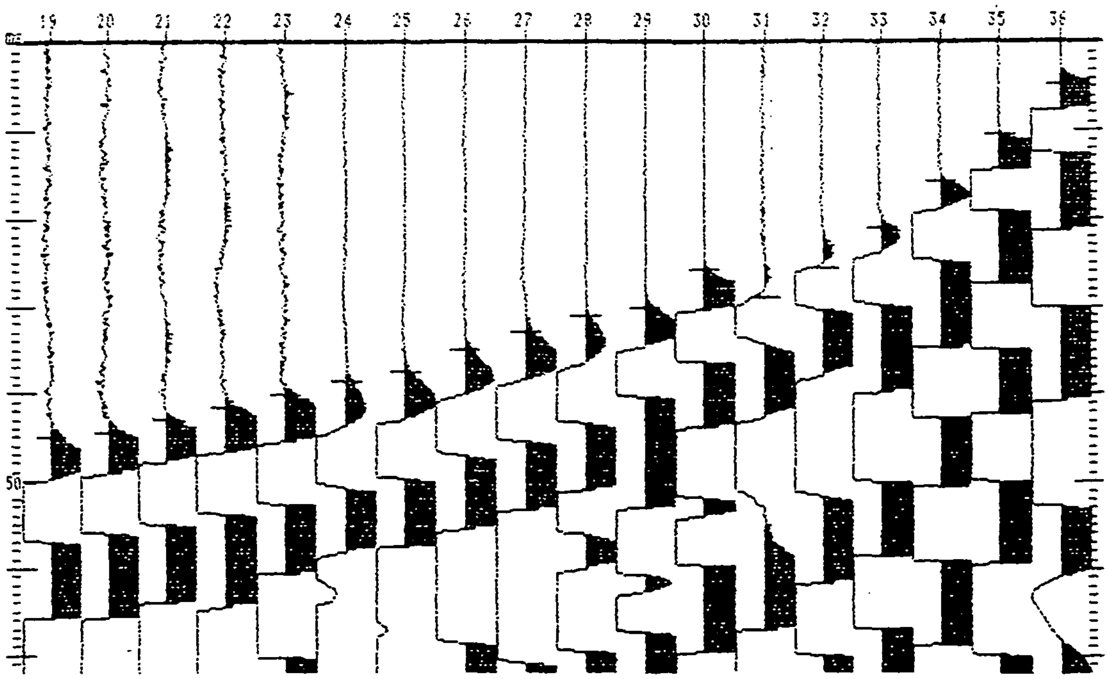
Channel:3



Profile ID: CHIREDZI1/CWWE
Project: BGS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF L
Comments: CLEAR CALM HOT WEIGHT E

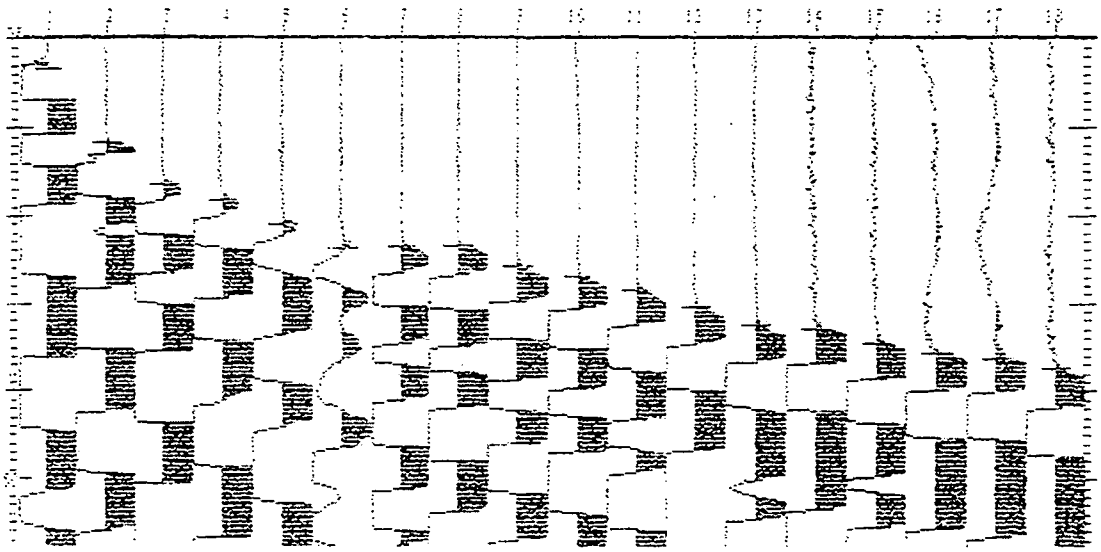
Method: Automatic
Date: 94/03/10
Created: 08:29
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel:3



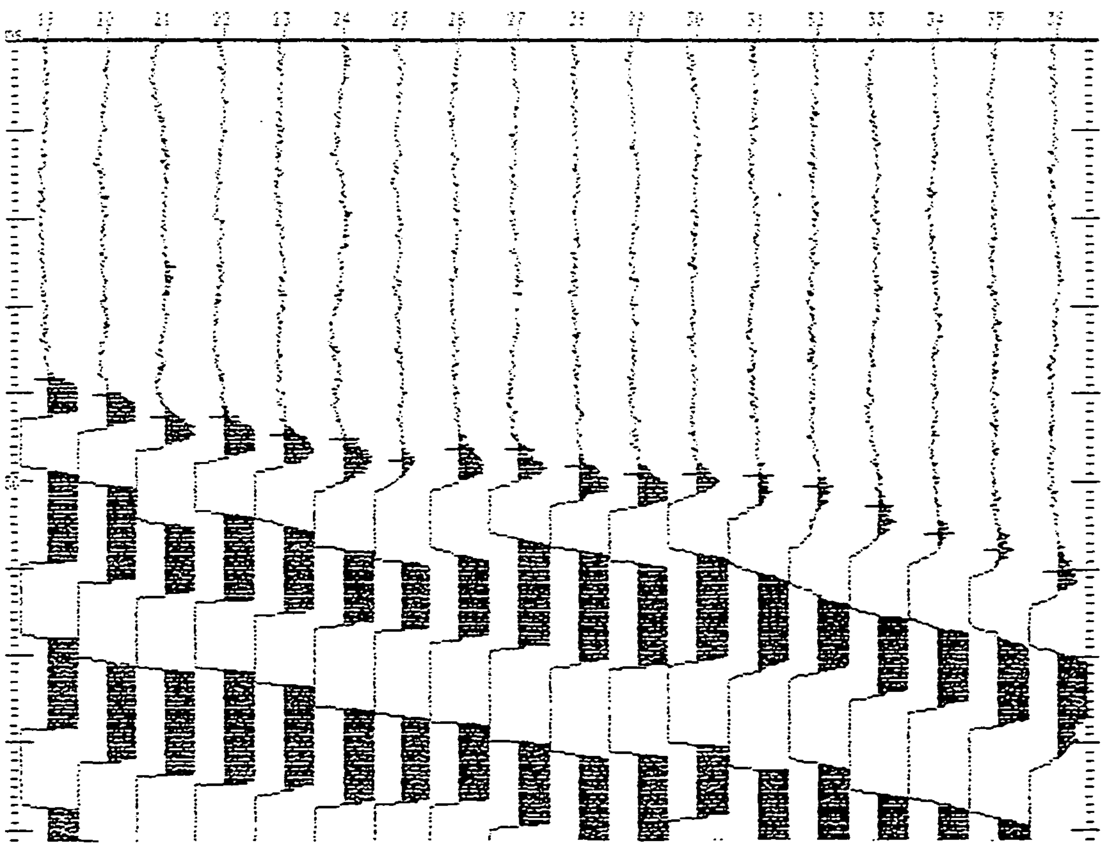
Profile ID: [illegible] | Method: [illegible]
Project: [illegible] | Date: [illegible]
Customer: [illegible] | Created: [illegible]
Cust. ref.: [illegible] | Geoph. spacing: [illegible] m
Operator: JEFF | Shot spacing: 3.0 m
Comments: CLEAR HOT CALM [illegible] | Start offset: 1.5 m

Channel:1



Profile ID: CHIREDZI2/CWME | Method: Automatic
Project: BGS | Date: 94/03/10
Customer: ODA | Created: 11:11
Cust. ref.: ODA | Geoph. spacing: 54.0 m
Operator: JEFF | Shot spacing: 3.0 m
Comments: CLEAR HOT CALM STEEL E | Start offset: 1.5 m

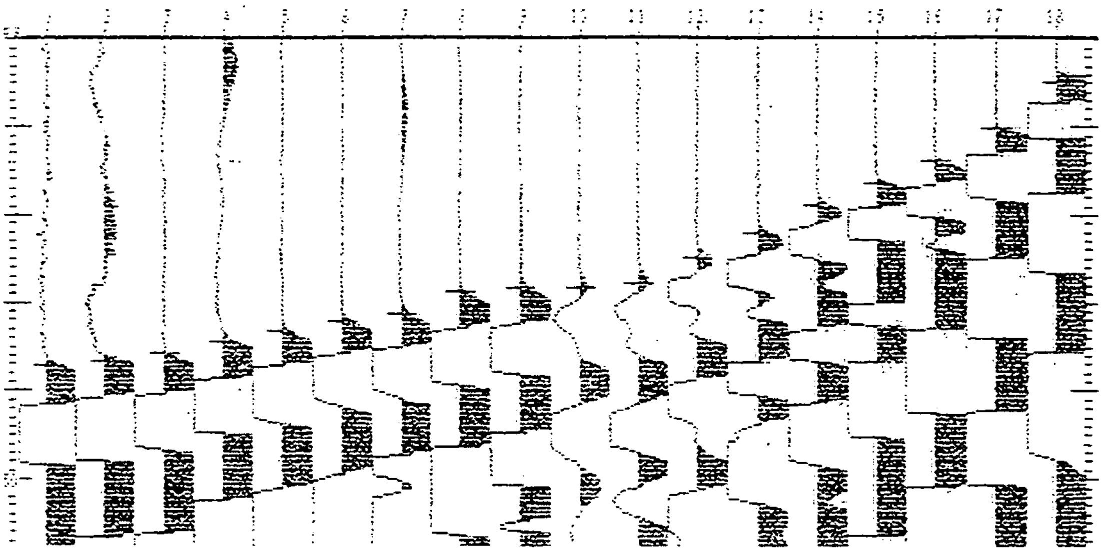
Channel:1



Profile ID: CHIREDZI1.CWWE
Project: 656
Customer: ODA
Cust. ref.: ODA
Operator: JEFF
Comments: CLEAR HOT CALM STEEL E

Method: Automatic
Date: 94/03/10
Created: 11:11
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

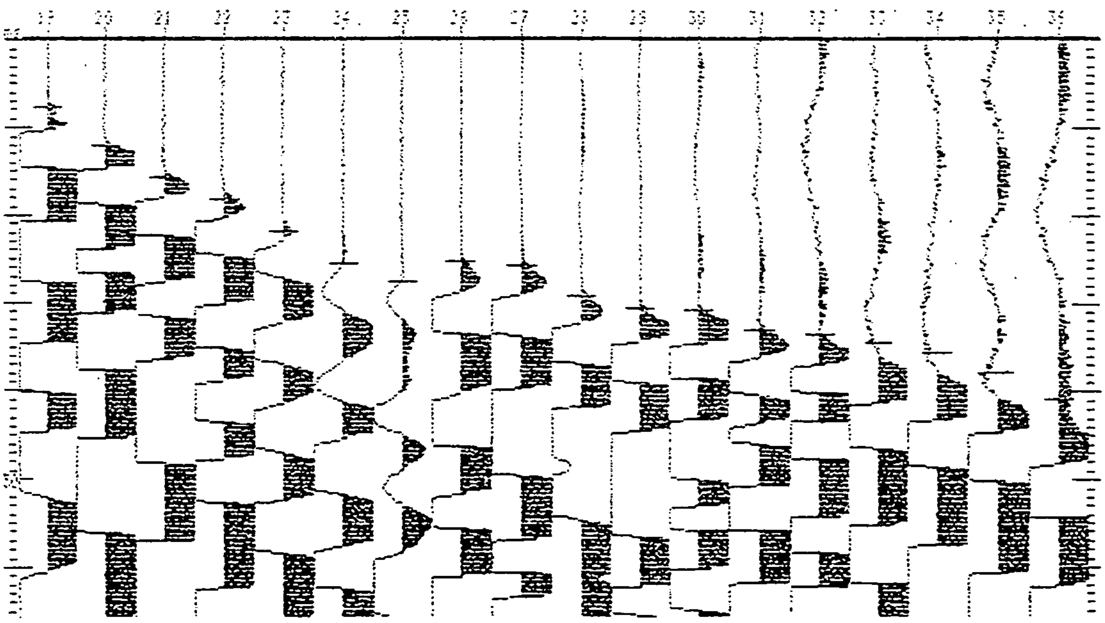
Channel: 1



Profile ID: CHIREDZI2/CWWE
Project: 383
Customer: ODA
Cust. ref.: ODA
Operator: JEFF
Comments: CLEAR HOT CALM STEEL E

Method: Automatic
Date: 94/03/10
Created: 11:11
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

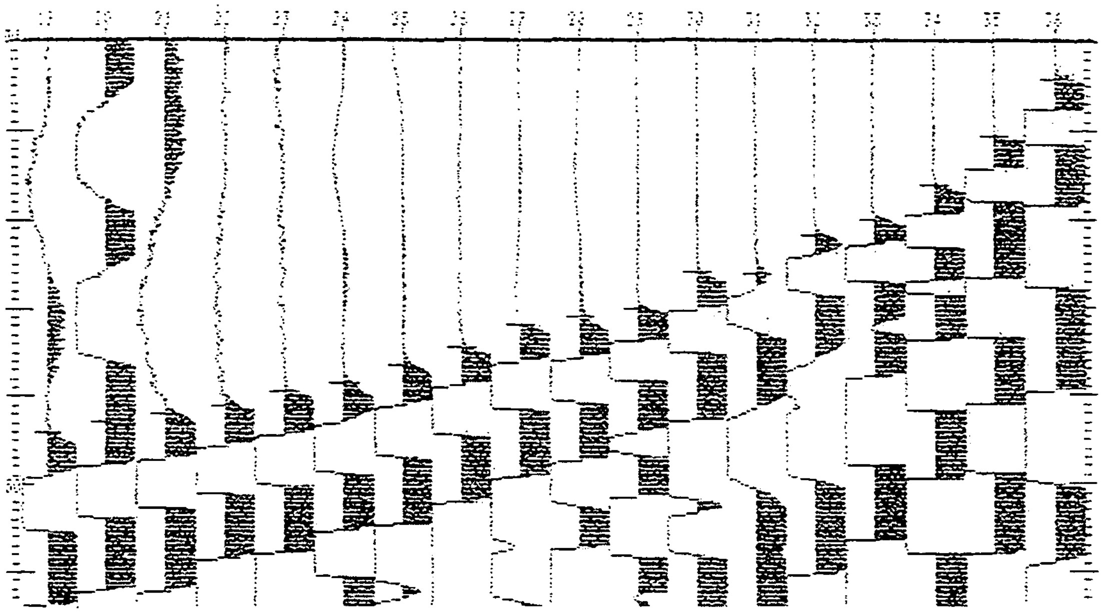
Channel: 2



Profile ID: CHIREDZI2/OWWE
Project: SEE
Customer: ODA
Cust. ref.: ODA
Operator: JEFF L
Comments: CLEAR HOT CALM STEEL F

Method: Automatic
Date: 84/03/10
Created: 11:11
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel: 3



Profile ID: CHIREDZI2/OWWE
Project: BSS
Customer: ODA
Cust. ref.: ODA
Operator: JEFF L
Comments: CLEAR HOT CALM STEEL E

Method: Automatic
Date: 84/03/10
Created: 11:11
Geoph. spacing: 54.0 m
Shot spacing: 3.0 m
Start offset: 1.5 m

Channel: 3