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DEPARTMENT OF
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EXPLOSIVE TESTS FOR COMPARISON OF SEISMIC EFFICIENCY OF MOLANITE, TNT, AND ANZITE BLUE, VICTORIA, MARCH 1974

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CONTENTS

ILLUSTRATIONS

SUMMARY

Field tests were conducted on 11 March 1974 in Waiaa, Victoria to compare the seismic efficiency of Molanite, TNT, and Anzite Blue. Seismic energy generated by equal amounts of each explosive was recorded in identical conditions, and the amplitudes of the refracted and reflected waves were measured and compared. The comparisons indicated that Molanite and Anzite Blue were equally efficient whereas TNT was about 10 percent less efficient. No significant difference was observed in the character of the seismic energy generated by any of the explosives tested.

INTRODUCTION

Anzite Blue, Geophex, and Nitropril have been used as sources of seismic energy by the Bureau of Mineral Resources (BMR) land seismic survey parties in the past. On information that TNT (trinitrotoluene) could be available from the Munitions Filling Factory of the Department of Supply at a cheaper cost than Anzite Blue it was decided to conduct field tests to determine the relative seismic efficiency of TNT and Anzite Blue, the most commonly used seismic explosive. At about the same time, I.C.I. Australia Limited also offered on the market a newly manufactured explosive, Molanite, with claims of improved safety and performance over the other explosives used for seismic work. It was therefore decided to include Molanite in the comparison tests.

Some of the important characteristics of Anzite Blue, TNT, and Molanite are given in Table 1. Anzite Blue is specially prepared by I.C.I. for seismic prospecting use and is available packed in Geolok plastic tubes in two sizes: 2.5 in. diameter, 4 lb 12 oz weight and 3.25 in. diameter, 9 lb 8 oz weight. TNT can also be supplied by the Munitions Filling Factory in Geolok tubes and sizes suitable for BMR seismic work. Molanite is presently available packed in thin plastic tubing, but it is understood from the manufacturers that it would be available later in Geolok tubes and in sizes appropriate for seismic use. Anzite Blue is a nitroglycerine-based explosive.

Molanite is formulated from non-explosive ingredients, principally ammonium nitrate, sodium nitrate, water, and aluminium.

SELECTION OF AN EXPLOSIVE

The choice of an explosive for seismic shooting purposes is based on its cost, both of purchase and transport, and its performance, that is its effectiveness as a source of seismic energy and the ease and safety of handling in the field. The characteristics which influence the amplitude and quality of seismic waves generated are velocity of detonation, brisance (a measure of shock wave produced), and strength. Those which affect its ease of handling and safety in the field include its weight, density, stability, water resistance, and inflammability (Richard & Pieuchot, 1956). Most of these parameters for the main explosives used have been derived from tests in the laboratory, but no direct relations have been established in the field between these parameters and the character of the seismic energy in the refracted/reflected waves that are generated. Tests by Taylor, Morris & Richards (1946) and Dobyns (1947) have shown no significant difference in the character of the refracted first arrivals at distances of 1.8 to 6 km or of reflected waves from explosives with velocities of detonation in the range of 1.1 to 7.5 km/s or with strengths of from 61 to 85 percent blasting gelatine. A noticeable amount of higher-frequency components were however observed in records from smaller (about 0.68 kg) charges than in records from larger (about 1.36 kg) charges. Thus it is difficult to determine the seismic efficiency of an explosive on the basis of its physical characteristics alone.

A more useful parameter, referred to as the Coefficient of Seismic Efficiency (CUS, in French abbreviation), has been proposed by Richard & Pieuchot (1956) for comparing the seismic effects of the explosives. The CUS is a measure of the relative amplitude of the seismic energy recorded from explosives of equal weight in identical conditions. Experiments by these authors show that the CUS does not depend on the size of the charge or on the field conditions; it depends only on the type of explosive.

Richard & Fieuchot suggest that to determine the CUS correctly, experiments should be designed to ensure:

- identical shot conditions,
- constancy of the recording equipment parameters, and
- repeatability and sufficient number of repetitions for a statistical analysis.

As the output of a shot is affected by the ground conditions in the vicinity of the shot hole, shot depth, tamping etc., it is important to ensure that variations in these are kept to a minimum. One way to achieve this is to shoot in a quiet body of water.

The constancy of the recording equipment can be ensured by conducting the tests over at least two days whenever possible and leaving the instruments set up in the field overnight. The gain of the recording system must be kept the same during the experiments, the AGC is turned off, and the filtering is reduced to a minimum. For the gain to be the same, the frequency of the signal should also be the same.

The experiments are repeated for each explosive of the same weight, the number of repetitions depending on the accuracy desired. The amplitudes of all the recorded traces for all the shots of the same explosive are averaged. By statistical averaging, random errors including the slight variations in the sensitivity of the equipment during the test are eliminated. The standard deviation is calculated to determine a measure of the accuracy obtained.

The relative averaged amplitudes of the seismic energy recorded is then a measure of the relative seismic efficiency of the explosives tested. From this relation, another relation between the costs of the explosives for the same seismic efficiency, necessary to determine the most economical explosive, can be obtained as the amplitude of seismic refracted waves has been suggested by Gaskell (1956) to be roughly proportional to the weight of the charge, for weights up to 200 lb (91 kg) at a distance of about 6 km from the geophones.

FIELD TESTS AND RESULTS

Field tests for comparing the seismic efficiency of Anzite Blue, TNT, and Molanite were conducted on 11 March 1974 during the Goulburn Valley Seismic Survey near Waiaa, Victoria. A geophone spread, 800 m long, was laid out in a split-spread as shown in Plate 1. Single geophones, Type GSC-20D (8Hz) were used at each detector position to pick up the seismic energy and SIE PT-700 equipment was used for the recording. A Sprengnether Engineering Seismograph was also used to record the energy at about 300 m (near geophone station 21) from the shots.

Holes were drilled 10 m deep in a retangular pattern with a spacing of 7 m, as shown in Plate 1. The explosive charge for each shot consisted of 4 lb 12 oz (2.15kg) of explosives loaded in a single hole and tamped with water.

Initial shots of TNT in Hole 7 were used to determine the optimum gain settings for the recording instruments. For the tests, the gain of the recording amplifiers was set at -80 dB for the inner 8 traces and at -50 dB for the remaining (16) outer traces. The filter settings were kept at L16-Out for the inner four traces and at Out-Out for the rest. The Sprengnether Seismograph gain was set at 100.

For comparison tests each type of explosive charge was shot four times in single holes as indicated in Plate 1, and four sets of records each were obtained from the geophone spread and from the Sprengnether. Set 1 consisted of shots 1, 2, and 3; set 2 of shots 4, 5, and 6; set 3 of shots 10, 11, and 12; and set 4 of shots 13, 14, and 15.

Typical records from the geophone spread and the Sprengnether are shown in Plates 2 and 3. The closest six traces in the geophone records were saturated after the first breaks and were used to measure the first-break deflection amplitudes only. The remaining traces clearly showed the character of the total seismic energy recorded at those distances. The maximum trough amplitudes of a reflection at about 0.08 s after the first breaks were measured on traces 1 to 6, 19 to 22, and 24 where this signal was undistorted.

On the Sprengnether records, the amplitudes of the first-break deflection and a signal about 80 ms later, corresponding to the reflection on the geophone record, were measured.

The amplitudes for each set of comparison records were measured on an arbitrary scale and adjusted on the basis of 100 as the amplitude for Anzite Blue records. As shown in Table 2, they are listed in four groups according to the recording instruments, geophone, or Sprengnether, and to the type of signal measured, refraction first-break, or reflection maximum amplitudes. Each group consists of the four sets of comparisons between Anzite Blue, TNT, and Molanite. The values given for the geophone spread are the sums of the first-break deflection amplitudes recorded on traces 10, 11, 14, and 15, and the sums of maximum trough amplitudes of the reflection recorded on traces 1 to 6, 19 to 22, and 24 for each record. The values for the Sprengnether are for the vertical component only.

Within each group the amplitudes for each explosive show up to ±12% variation between the different sets of values (Table 2). This variation is considered to be due to the variation in the individual shot-hole conditions in the area where large variations in near-surface sandy layers are known to exist. The mean of all the measurements is calculated to be 103.8 for Molanite and 89.9 for TNT when compared to 100 for Anzite Blue and the standard deviation for both is about 7 percent.

Although the total weight of each explosive used, including the container tubing, was equal, it is estimated that the amount of Molanite in the lighter thin plastic tubing was somewhat (about 5%) greater than that of TNT and Anzite Blue in the heavier Geolok plastic tubes. Thus, for practical purposes, Molanite is considered to be about as efficient as Anzite Blue.

Three traces recorded from the three types of explosives by geophones 1 and 21 are compared in Plate 4. The character of the energy recorded from each explosive appears to be the same, thus implying little variation in the frequency content of the energy generated by each explosive.

CONCLUSIONS

From field tests comparing the amplitudes of the refracted and reflected energy recorded from the three types of explosives, it is concluded that Molanite is about as efficient as, and TNT about 10 percent less efficient than, Anzite Blue.

No significant difference was observed in the character of seismic energy obtained from any of the explosives tested.

Molanite is considered to be the safest to handle, being formulated from non-explosive ingredients and it is claimed by the manufacturer not to detonate by the impact of heavy falling weights c.f. nitroglycerine-based explosives which will detonate in these circumstances. Although the thin plastic tubing in which it was packed for the tests was undesirable because of the danger of being ripped open while loading, it should be as easy and safe to load as Anzite Blue when packed in the more robust Geolok plastic tubes.

TNT requires a special primer, RDX, for detonation and therefore the factory-made charge cannot be cut into smaller pieces for use as smaller charges. It is rigid and hence does not snake down uneven holes as easily as Anzite Blue.

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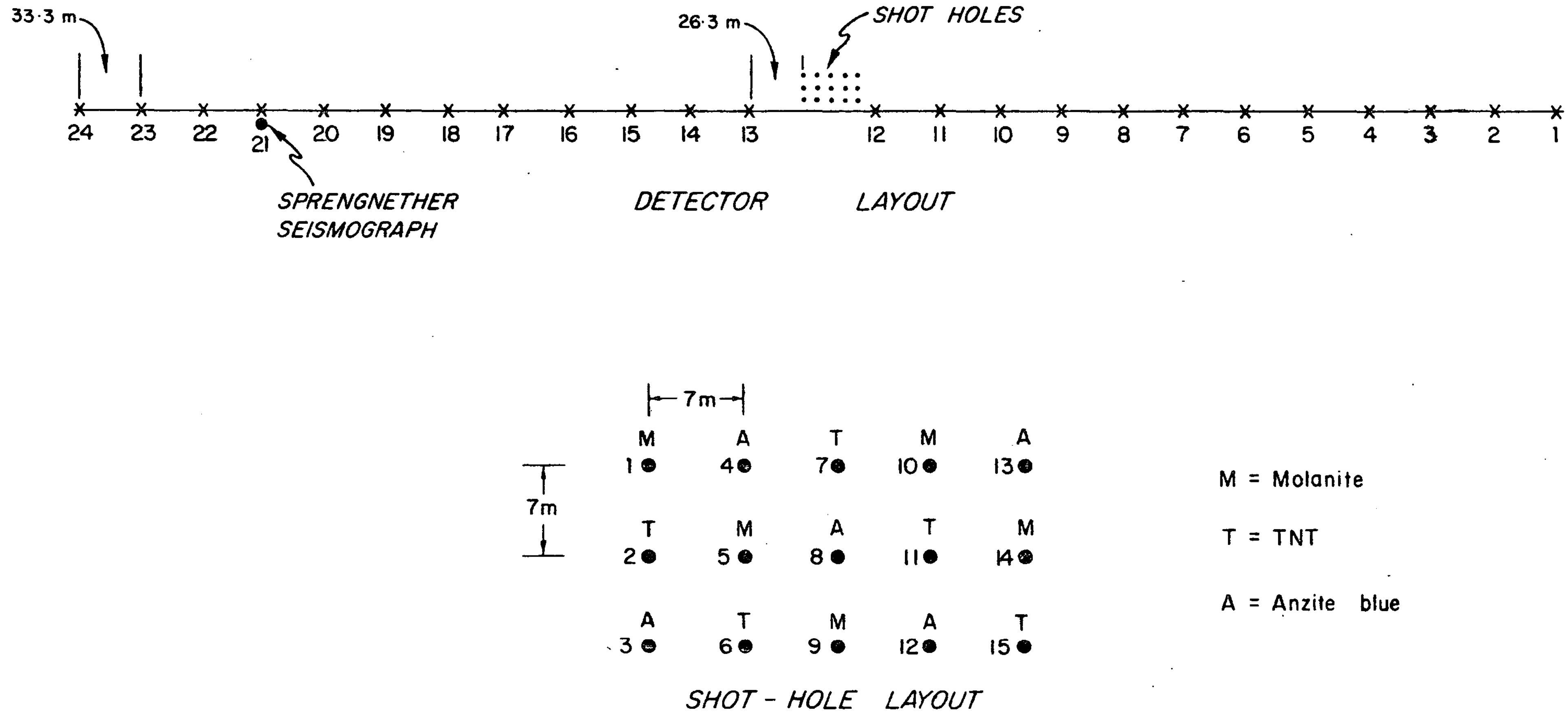
Table 1. Main characteristics of the seismic explosives tested.

Name	Type	Density g/cm^3	Velocity of detonation m/s	Rigidity of charge	Comments
Anzite Blue	Gelatinous, nitroglycerine-based	1.40	4200	Plastic	Unsafe to impacts, water resistant, easy to load
TNT	Trinitrotoluene-based	1.60	6640	Rigid	Safe to impacts, chemically stable, excellent water resistance, not easy to load in uneven holes, requires RDX primer
Molanite	Slurry, non-explosive ingredients, weight strength 110	1.20	3000	Soft	Safe to impacts (including bullets), resistant to sympathetic detonation, excellent water resistance, no noxious fume properties, burns with difficulty

Table 2. Relative amplitudes of refracted and reflected energy from the explosives tests.

Type of records	Group	Set	Molanite	TNT	Anzite Blue
GEOPHONE SPREAD RECORDS	First-break deflection amplitudes	1	104.8	93.5	100
		2	101.8	87.5	100
		3	100.0	84.8	100
		4	94.1	86.3	100
	Reflection maximum trough amplitudes	1	106.5	99.2	100
		2	96.4	82.6	100
		3	99.1	94.6	100
		4	99.0	89.3	100
SPRENGNETHER SEISMOGRAPH RECORDS	First-break deflection amplitudes	1	110.3	96.6	100
		2	100.0	78.6	100
		3	110.9	92.7	100
		4	119.6	93.1	100
	Reflection maximum peak amplitudes	1	114.7	100.0	100
		2	100.0	79.1	100
		3	107.0	96.5	100
		4	97.3	84.7	100
MEAN			103.8	89.9	100
STANDARD DEVIATION			6.96	6.66	

Record No. 1974/168

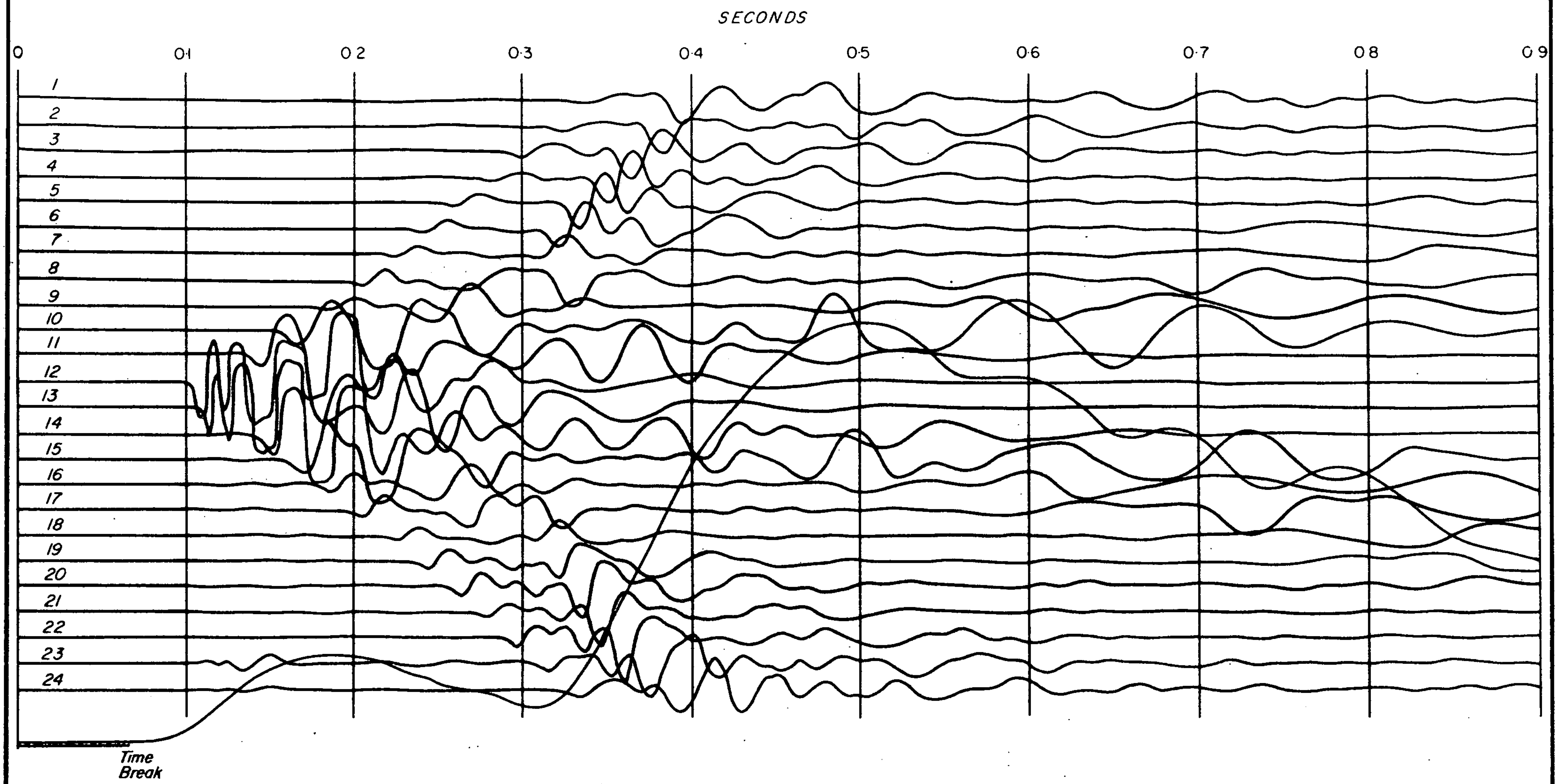


DETECTOR AND SHOTHOLE LAYOUT

PLATE 1

G85/3-201A

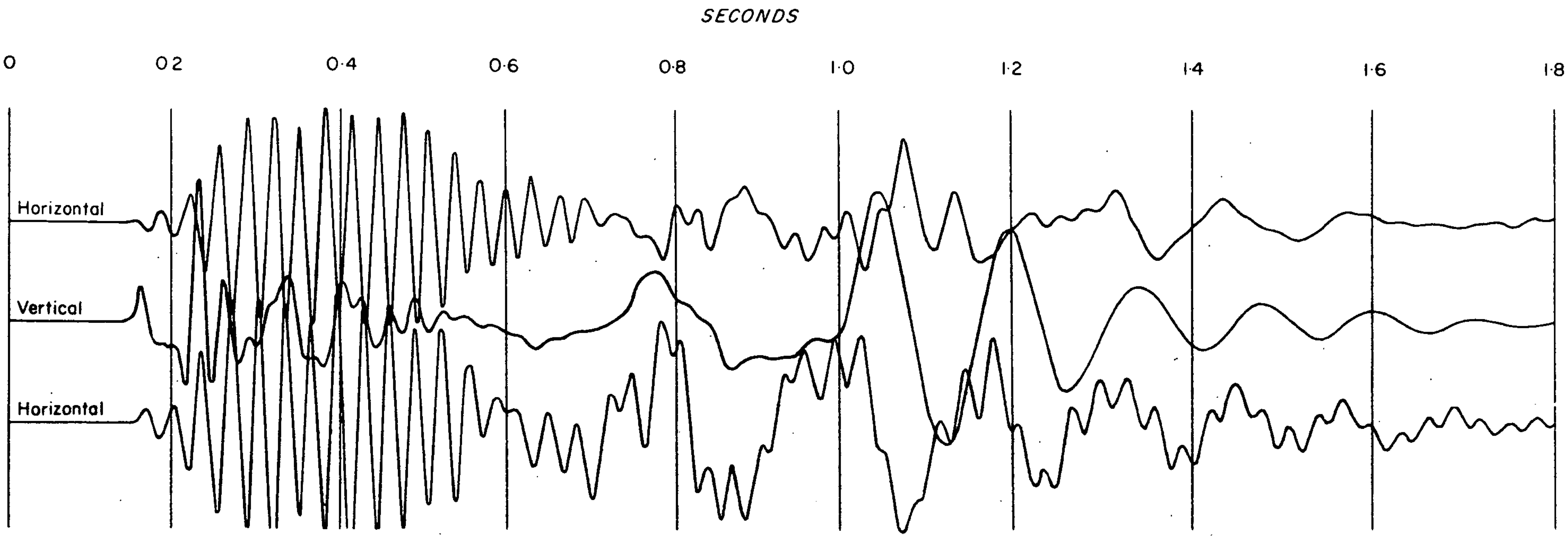
Record No. 1974/168



TYPICAL GEOPHONE — SPREAD RECORD FROM TNT

PLATE 2

G85/3-202A

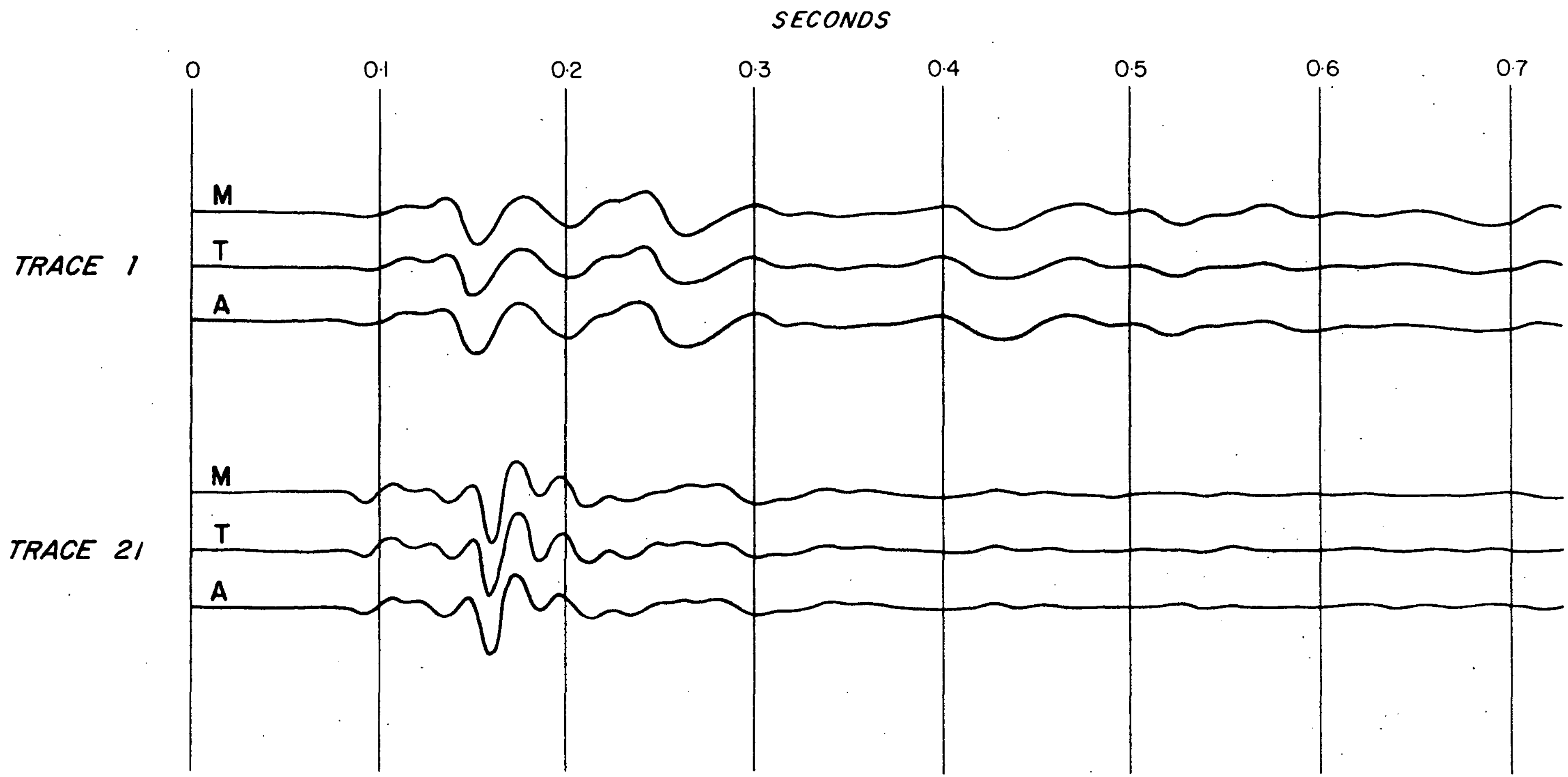


TYPICAL SPRENGNETHER SEISMOGRAPH RECORD

G85/3-199A

PLATE 3

Record No. 1974/168



M = Molanite
T = TNT
A = Anzite blue

COMPARISON OF TRACES RECORDED FROM MOLANITE, TNT, & ANZITE BLUE

PLATE 4

G85/3-200A