DEPARTMENT OF MINES AND ENERGY
GEOLOGICAL SURVEY
SOUTH AUSTRALIA

REPORT BOOK 92/50

SOIL AIR CO_2/O_2 PROJECT: PROGRESS REPORT I, MOUNT LOFTY RANGES

by

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DR I G WATMUFF

1. INTRODUCTION

Soil air carbon dioxide and oxygen measurements as a guide to oxidizing sulphide have been assessed by several researchers and government geological surveys in the United States, Ireland, Africa and Saudi Arabia (Lovell et al 1983; Hinkle and Dilbert, 1984; Reid and Rasmussen, 1990; Ball et al, 1990 and McCarthy Jr and Bigelow, 1990). The rationale is that sulphide oxidation in the presence of water and oxygen will produce sulphuric acid which in turn will attack any carbonates present to produce CO_2. Oxygen is consumed in the process. Both CO_2 and O_2 are easily measured to an acceptable accuracy in the field with portable equipment.

2. REVIEW

Several sulphur gas species may be generated by weathering sulphides including SO_2, COS (carbonyl sulphide) and H_2S depending on the availability of oxygen eg Taylor et al (1982) and Hinkle et al, (1990).

Sulphuric acid is probably generated (1) directly as a result of sulphide oxidation in the presence of water and oxygen and (2) in secondary reactions between sulphur dioxide and other volatile sulphur species and water.

In a study of the production of sulphur gases and carbon dioxide from synthetic weathering of crushed pyrite/chalcopyrite ore from the Santa Cruz porphyry copper deposit, Arizona, Hinkle et al (1990) found the main head space species present to be CO_2, O_2 and SO_2 in both wet and humid conditions. Carbonyl sulphide (COS) and Carbon disulphide (CS_2) were very minor, often below detection (40 ppb) and showed poor correlation with both pyrite and total sulphur content of the samples.

Moreover Graedel (1977) states that the persistence of H_2S in open air is restricted to one day and CS_2 to 40 days but COS persists for about 600 days.

The partial pressures of SO_2 and CH_3SH in the presence of water are so low that these species are unlikely to reach the near surface layer of soil except perhaps under extremely dry or shallow oxidizing conditions such as at Silver Bell (Hinkle and Dilbert, 1984).

Of all sulphur species likely to be generated by sulphide oxidation, COS appears to show the most promise as an exploration tool (Oakes and Hale, 1987). However, like the other sulphur species, the levels in soil air are so low (ppb-ppt) that the only practical way of measuring these gases is by desorbing soil samples, and determining the head space gases using specialized gas chromatography.

2.1 Factors Affecting Soil Air CO_2 and O_2 levels

Apart from sulphide oxidation, soil CO_2 and O_2 values are influenced by several factors. Biological CO_2 is produced by microbial decomposition of soil organic matter and root respiration. The bacteria Desulphovibrio desulphuricans generates metabolic CO_2 during reduction of sulphates to sulphides. Hence soil moisture level, temperature and ecosystem have an important influence.

In tropical soils, CO_2 values higher than 10% have been recorded (Vine et al, 1943; Zenn and Li, 1960). However, in the more arid climate of Nevada, USA, Amundsen et al (1989) report a highest value of 0.16% CO_2. In a subtropical-arid to tropical climate in Arizona, Parada et al (1983) reported a highest value of 0.75% CO_2. Normalizing % CO_2 by dividing % CO_2 by % organic carbon in the top 1m of the profile, virtually eliminated much of the variation in soil air CO_2 between different climate/vegetation (elevation) zones in the hills of the Mojave Desert (Amundsen and Davidson, 1990).

Soil moisture is important. Provided soil moisture levels remain above the permanent wilting point, CO_2 values rise as soil temperature rises. However if the moisture level drops below the permanent wilting point, the correlation will not remain and CO_2 levels fall.

Increasing vegetation density, increasing tree size, and increasing leaf litter all give increased soil CO_2 levels (Parada, 1983; Crowther, 1983). Differences in forest types appear to have large effects on CO_2 levels (Zenn and Li, 1960).

Soil CO_2 levels generally increase with depth in the top 1 m of the profile, the greatest variation occurring in the top 30 cm. The greatest variation is noted in tropical soils whereas arid to semi arid soils show only slight increases or no increase below about 30 cm (tabulated data, Amundsen and Davidson, 1990).

Soil permeability may significantly influence the CO_2 flux. Singh and Gupta (1978) found that measured rates of CO_2 flux were highly variable and ranged from 0 to 4000 mg CO_2 m^{-2} hr^{-1}. High CO_2 levels tend to accumulate in the soil as a result of stimulated production and restricted diffusion of gases. In a montane soil in Utah, Solomon and Cerling (1987) found that high CO_2 levels developed in the early spring, as saturated conditions at the soil surface effectively capped the soil, and prevented CO_2 transport to the atmosphere. In sandy loam soils in an irrigated Riverland, SA, citrus orchard, CO_2 levels under compacted vehicular tracks were found to be 1.5 to 5 times higher than under non-compacted surfaces.

In conclusion, soil air CO_2 and O_2 measurements as a guide to sulphide mineralization are likely to be most reliable in arid and semi arid environments where vegetation cover is sparse and has a consistent density. Complex soil profiles with low permeability layers need to be carefully assessed in data interpretation and sampling. For texturally homogeneous profiles a sampling depth of 75 cm appears optimal and this is the most common sampling depth quoted in the literature.

3. APPLICATION OF SOIL CO_2 AND O2 ANALYSIS TO MINERAL EXPLORATION IN SOUTH AUSTRALIA

Soil air CO_2 and O_2 measurements appear to have good potential application to sulphide mineralization in South Australia where barren surface cover and deep weathering up to several tens of metres thick obscures much mineralized geology. Eyre Peninsula is a typical example. Here many prospective host rocks are carbonate bearing providing the ingredients for CO_2 production. It is possible sulphur species including SO_2 may migrate upwards to react with a moistened calcrete horizon (widespread over much of SA) to generate CO_2 anomalies.

The semi arid to arid climate should provide optimum anomaly contrast and reduce the incidence of biologically generated false anomalies.

4. METHOD OF INVESTIGATION

A stainless steel probe, inner diameter 3 mm, outer diameter 9 mm, length 2 m and internal volume of

15cc is hammered into the soil. Typically the tip of the probe is driven 75 cm below the soil surface unless rock or extremely hard ground conditions are encountered. The top end of the probe is sealed with a rubber septum through which a needle is inserted and air drawn into a 20cc syringe Plates 1,2 and 3).

The first 20cc is discarded and a second 20cc is taken as the sample. This is injected into a portable battery powered infra red CO_2 analyser and a paramagnetic O_2 analyser and readings recorded immediately. The CO_2 analyser has a stated relative accuracy of ± 2% of scale reading and is calibrated with a standard gas mixture (4.74% CO_2 ± 0.09% in N_2). When zeroed, the atmospheric CO_2 level consistently reads 0.04% instead of the expected 0.03%. At 0.50% CO_2 the reading is 0.52% CO_2.

5. CASE HISTORIES

5.1 Kanmantoo Group

Six sites (figure 1), all within Kanmantoo Group meta sediments of the Adelaide Geosyncline, were chosen for evaluation.

5.1.1. Mount Torrens Ag-Pb-Zn prospect

A single E-W traverse was made normal to bedding strike across the prospect and coincided within a few metres to CRA grid line 600S (CRA Exploration Pty Ltd., 1979). Two holes, P4 and P12 drilled parallel to the section and dipping about 60^o west give good geological control along a portion of the traverse. The soil CO_2 and O_2 data are given in table 1a and plotted together with relevant geological data in figure 2A.

The terrain is hilly and the soil a shallow fine grained very compact, red-brown residual clay loam, possibly grading to saprolite within 30-75 cm of the surface. Extreme difficulty was encountered in driving the sample probe tip to 75 cm, hence a depth of 50 cm was used for this traverse. Vegetation comprised open dry grassland.

Interestingly the metasandstone rather than the Nairne Pyrite Member yielded the higher CO_2 background (0.5% CO_2 compared to 0.3% CO_2). No convincing anomaly was observed possibly reflecting low to zero carbonate levels in the Nairne Pyrite Member here. No obvious soil texture or structure difference was noted which could affect CO_2 flux.

Fortuitously no sample was taken over the base metal mineralized horizon ("mineralized quartzite zone"-Fig 2A) due to very hard ground conditions for the probe. This should be reattempted. More closely spaced sampling, say at 5 m intervals, should be carried out between the two drill holes where there is a broad horizon with pyritic bands (1-20% pyrite-CRA report Env 2838) (Fig 2A). Later work has suggested that anomalies may be finely resolved where pyrite oxidation is occurring at a shallow depth in narrow zones.

Ground magnetics along the same traverse showed no correlation with $CO_2/\Delta O_2$ values nor any significant correlation with known mineralization (Appendix, Traverse 3750N).

<u>Addendum</u>

The same traverse was repeated 6 months later on 20/5/92 after a dry spring and summer and following drought breaking rains about one week prior to the survey. Although the soil was wet, air was easily drawn from the soil through the probe into the syringe. Probe penetration was much easier, and ground found too hard previously (10 W to 15 E) was easily penetrated and sampled. The soil air was apparently fairly humid as slight condensation was observed to build up within the syringe after several samples.

The carbon dioxide levels were found to double the early summer readings over the Nairne Pyrite member and the mineralized quartzite and quartz-biotite schist to the west. However readings over the metasandstone (unmineralized), to the east has remained about the same (Table 1b and Fig 2B).

The oxygen deficit ($\Delta 0_2$) is several times high than 6 months ago indicating the higher oxygen demand usually characteristic of wetter conditions. Here, this could be due to biological (chiefly microbial) activity or sulphide oxidation or both.

The soil over unmineralised metasandstone consistently has a high oxygen defect relative to $C0_2$ level. The western 5 or 6 samples also show a very large oxygen deficit relative to $C0_2$. The extent of mineralization beneath these sites is unknown. Surface inspection of saprolite exposure in the nearby dam (Fig 2A) does not reveal evidence of oxidized sulphide. Angled drill hole MTP4 beneath the traverse passed through no sulphide west of 5 mE, however the deeper hole, MTP12 further beneath MTP4, was still within sulphide (1-2% pyrite) as far west as 5 mW (Fig 2B).

If the high oxygen defect relative to CO_2 is indicative of a lack of CO_2 produced by sulphide oxidation ie if all CO_2 in these samples is produced by microbial activity, then various mathematical filters can be used to enhance the real anomaly. These filters should preserve the shape and magnitude of the CO_2 profiles where $CO_2/\Delta O_2$ is approximately unity and reduce the significance of CO_2 values where the oxygen defect is above the CO_2 value and visa versa. Two suggested filters are plotted in figure 2B.

5.1.2. Monarto Traverses

5.1.2.1 **Tepko Road**

Running NW from the township of Monarto, the Tepko road crosses the on-strike projections of two-significant conformable pyritic horizons in the upper part of the Kanmantoo Group metasediments (Fig. 3).

The Kanmantoo geology along the road is hidden beneath an unknown thickness of unconsoldiated to consolidated sand mapped as recent shallow alluvial deposits of creek channels and flood plains.

a) <u>Eastern Pyritic Horizon</u>

In a survey carried out on 18/11/91 a distinct CO_2 and ΔO_2 anomaly was detected over the projected strike position of the eastern of the two above mentioned pyritic horizons (Fig. 3). This anomaly was reconfirmed one month later on 18/11/91 and 4 months later on 11/3/92 (Fig. 4). The data are presented in Table 2. The background values for the first survey showed little variation (0.4-0.5% CO_2 and 0.2-0.3 Δ % O_2) despite variation in vegetation. About 50% of the ground area is covered by mallee and acacia bushes, the remainder by dead and dried grass less than 30 cm high.

The anomaly peak coincides with a road reserve traversed by a narrow, little used, dirt vehicular track winding through mallee and acacia. Considerable resistance was encountered here during probe insertion at 90mE probably due to soil compaction. This would render this high value suspect, however, the adjacent high value at 100mE was duplicated in much softer ground off the edge of the vehicle track.

Two parallel traverses carried out on 18/12/91, 20 m and 30 m north of the 18/11/91 traverse also yielded anomalous CO_2 values although these were less than 1% (Table 3). On 11/3/92, values of 1.07% CO_2 and 0.9% ΔO_2 were detected at a site about 30 m south of the original traverse and 7 m away from the edge of the vehicle track. A composite plan is given in figure 5 showing these data for CO_2.

Although anomalous values north and south of the original traverse enhance the anomaly, most of the higher values occurred in the harder, consolidated sand layer below the softer, unconsolidated sand. At 104mE, on the traverse 20m north of the 18/11/91 line, soil air measured 0.87% CO_2 and 0.5% ΔO_2 at 75 cm depth and about 15 cm into the harder base layer, whereas levels of 0.35% CO_2 and 0.2% ΔO_2 were detected at 50 cm depth and 10 cm above the harder base layer (Table 3).

A ground magnetic traverse gave no responses across this area (Appendix, Traverse 6117N-B).

b) <u>Western Pyritic Horizon</u>

An attempt was made to detect the projected western pyritic horizon along the Tepko road on 18/12/91. Anticipated target width was 50-120 m and a sample interval of 20 m was chosen. The data are plotted on figure 3 and tabulated in Table 4. All samples were taken in a harvested cereal paddock several metres in from the boundary fence.

Hard and soft sandy ground conditions were encountered as in the area around the projected eastern pyritic horizon. No clear correlation was observed between these conditions and $CO_2/\Delta O_2$ levels. No convincing anomaly was detected and background CO_2 values were 1/2 to 1/3 lower than around the eastern pyritic horizon.

A ground magnetic traverse yielded a low order peak at about 300mE not correlated with CO_2 values (Appendix, Traverse 6117N-A).

A much shorter traverse across the western horizon on 11/3/92 further north also yielded no anomalies (Fig. 3 and table 5), possibly indicating low pyrite content, narrow sulphide zones or lack of carbonate to generate CO_2.

Ground magnetic data along the same traverse simply gave steadily declining values from 59650 nT to 59370 nT from west to east (Appendix, Traverse 6118N).

5.1.2.2. **Onkaparinga-Murray Bridge Pipeline**

A few kilometres west of Monarto township, the Onkaparinga-Murray Bridge pipeline easement crosses another pyritic horizon within the Kanmantoo Group (Fig. 6).

Depth of probe penetration here was usually 50 cm. Vegetation consisted of dry grass with fresh germination. The results are presented in table 6 and plotted in figure 6.

Two soil air CO_2 peaks were noted and there was a close correlation with ΔO_2. These peaks possibly correlate with pyrite rich bands within the target horizon. Follow up ground magnetics failed to show any correlation with these peaks or show any anomaly at all (Appendix, Traverse 6117N-C).

5.1.3. Aclare Mine Traverse

A traverse was made along an east-west fence line across an alluvial flat about 400 m north of the old Aclare Pb-Ag-Au mine (Fig. 7). The target was a potential along strike continuation of the Aclare or related lodes. The data are tabulated in table 7 and plotted in figure 7.

The peak CO_2 value at 70mE was taken in a small creek bed, tributary to Dawesley Creek. All other samples were from soil whose surface was 1-2.5 m above the creek bed. Dawesley Creek carried abundant bright orange iron oxide precipitate probably derived from pyritic horizons in its catchment. The water is probably acid and lateral seepage may have given this high value.

5.1.4. Wheal Barton Mine

The Wheal Barton Mine lies approximately 5 km east of Truro. Copper ore was extracted from the mine as late as the 1920s. Three shafts were sunk on a near north-south trending line of lode (Fig 8).

The two northern shafts appear to have been opened on the lode outcrop and follow the mineralization down dip to the west at 60 to 70^o. The main shaft is vertical and sunk into the hanging wall.

Two traverses - traverse A 15-20 m south of the main shaft and traverse B, between the two northern shafts - were made to see if a $CO_2/\Delta O_2$ response could be obtained. Probe penetration was limited to 50 cm below surface due to hard ground conditions. Traverse A yielded relatively high values of $\geq$ 0.5% CO_2 but no obvious anomaly (Table 8). ΔO_2 correlates closely with CO_2. A clear $CO_2/\Delta O_2$ anomaly exists over the hanging wall along traverse B (Table 9).

The relatively high background values of traverse A are a little puzzling. Vegetation was minimal, dry grass and minor new germination. The paddock may have a history of high super phosphate application, with resulting soil acidification and calcium carbonate breakdown.

Traverse B occurs along a roadside reserve and mostly away from the influence of cultivation except perhaps for the two eastern most sites. Background here is significantly lower at about 0.35% CO_2.

5.1.5. Kanappa Mine Area - Sanderson

A short traverse was made across strike over limestone east of the Kanappa Copper Mine. The aim was to cross the strike of an outcrop of limonitic limestone a few metres wide. No anomaly was detected and the values for $CO_2/\Delta O_2$ were low (Table 10).

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PLATES

Plate 1. Inserting probe via sliding hammer (Photo No. 40264).

Plate 2. Extracting soil air sample via syringe (Photo No. 40265).

Plate 3. Injecting soil air sample into oxygen analyser (Photo No. 40266).

TABLE 1a

MOUNT TORRENS TRAVERSE
(CRA grid line 600S)

18/12/91

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
50mW	0.48	20.5	50	Slope, near-dried pasture grass
40mW	0.33	20.6	"	" "
30mW	0.37	20.7	"	" "
20mW	0.29	20.7	"	" "
10mW	0.29	20.7	"	" "
15mE	0.28	20.9	"	" "
25mE	0.34	20.8	"	" "
35mE	0.33	20.8	"	" "
45mE	0.31	20.8	"	" "
55mE	0.12	20.8	"	" "
65mE	0.19	20.8	"	" "
75mE	0.36	20.8	"	" "
85mE	0.41	20.7	"	" "
95mE	0.37	20.7	"	" "
105mE	0.19	20.8	"	Slope/valley "
115mE	0.28	20.8	"	Valley "
125mE	0.23	20.8	"	Slope "
135mE	0.47	20.6	"	" "
145mE	0.37	20.7	"	" "
155mE	0.53	20.6	"	" "
165mE - 178mE				outcrop "
				meta sandstone. "
185mE				Soil very shallow, "
195mE				Soil very shallow, "
205mE	0.73	20.4	"	Slope, near dried pasture grass
215mE	0.53	20.5	"	" "
225mE	0.44	20.6	"	" "
235mE	0.47	20.6	"	" "
245mE	0.51	20.6	"	" "
255mE	0.41	20.6	"	" "
265mE	0.57	20.5	"	" "
275mE	0.53	20.6	"	" "
285mE	0.46	20.6	"	" "
305mE	0.47	20.6	"	" "
325mE	0.55	20.5	"	" "
345mE	0.53	20.6	"	" "

* O_2 air reading = 20.9%

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TABLE 1b

MOUNT TORRENS TRAVERSE
(CRA grid line 600S)

20/05/92

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
50mW	0.70	19.4	50	Flate weed mat. 70%
40	0.61	19.7	"	ground cover. Probe
30	0.65	19.8	"	penetration much
20	0.88	19.4	"	easier than Nov 1991
15	0.64	19.7	"	Easy to pull gas. Air
10	0.50	20.1	"	moist.
5	0.59	20.2	"	"
0	0.35	20.5	"	"
5mE	0.79	19.5	"	"
10	0.49	20.2	"	"
15	0.30	20.6	"	"
20	0.19	20.8	"	"
25	0.35	20.6	"	"
30	0.31	20.6	"	"
35	0.54	20.3	"	"
40	0.54	20.3	"	"
45	0.68	20.0	"	"
50	0.85	20.0	"	"
55	0.76	20.2	"	"
60	0.58	20.3	"	"
65	0.31	20.5	"	"
70	0.21	20.7	"	"
75	0.54	20.0	"	"
80	0.63	20.2	"	"
85	0.39	20.4	"	"
90	0.57	20.2	"	"
95mE	0.37	20.5	"	"
100	0.24	20.6	"	"
105	0.14	20.7	"	"
110	0.32	20.5	"	"
115	0.38	20.5	"	"
125	0.26	20.6	"	"
135	0.31	(20.0)	"	(probably too low)
145	0.46	20.1	"	"

Table 1b (Continued)

20/05/91

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
155	0.21	20.6	50	(probably too low)
205	0.48	20.2	"	"
215	0.43	20.3	"	"
225	0.45	20.2	"	"
235	0.41	20.2	"	"
245	0.56	20.0	"	"
255mw	0.58	20.0	"	"

* Air reading = 20.9% O_2

TABLE 2

TEPKO ROAD (TRAVERSE OVER PROJECTED EASTERN PYRITIC HORIZON)
SOUTH SIDE OF ROAD

18/11/91

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
0mE	0.37	20.8	75	Dead grass
20mE	0.47	20.8	"	" + hop bush
40mE	0.44	20.8	"	" + hop bush
60mE	0.54	20.7	"	Mallee
80mE	0.62	20.4	"	Dead grass
81mE	0.77	20.6	"	"
90mE	2.82	18.6	65	Sparse green grass on dirt track
100mE	1.76	17.6	75	Mallee + dead grass
110mE	0.42	20.8	"	Dead grass
120mE	0.34	20.8	"	"
140mE	0.40	20.8	"	" + hop bush

Above traverse (one month later)

18/12/91

80mE	0.57	20.4	75	
90mE	1.95	20.1	70	
100mE	2.47	18.5	75	

* air reading = 21.0% O_2

\+ OmE = 35°4.1'N, 139°9'E Mobilong 1 mile sheet.

Above traverse (four months later)

11/3/92

80mE	0.60	20.3	75	Very minor fresh grass germination
85mE	1.04	20.0	75	
90mE	1.43	19.3	75	
100mE	2.03	17.5	75	
105mE	0.61	20.5	75	

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110mE	0.50	20.6	75

TABLE 3

TEPKO ROAD (TRAVERSES OVER A PROJECTED EASTERN PYRITIC HORIZON)
NORTH SIDE OF ROAD (Approx 20m grid north of south side road traverse)

18/12/91

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments	
48mE	0.46	20.7	75	Mallee	
58mE	0.53	20.7	75	Mallee	
68mE	0.26	20.7	75	Mallee, dried grass	
78mE	0.38	20.7	75	"	"
88mE	0.50	20.6	75	"	
				Probe tip in hard sand	
98mE	0.69	20.5	75	As above	
104mE	0.87	20.5	75	Hard sand below 60 cm	
104mE	0.35	20.8	50	Soft sand above 60 cm	
108mE	0.83	20.5	75	Probe tip in hard sand	
118mE	0.31	20.8	75	Soft sand	
128mE	0.27	20.9	75	Hard sand below 70 cm	

Parallel traverse approx 12m grid north of above in cereal paddock with dried stubble.

80mW	0.82	20.4	75	Hard sand below 25 cm
90mW	0.85	20.4	75	Firm most of profile
100mW	0.46	NR	75	Hard below 65-70 cm

* air reading = 21.0% 0_2

NR = not recorded

TABLE 4

TEPKO ROAD (PROJECTED WESTERN PYRITE HORIZON TRAVERSE)
NORTH SIDE OF ROAD A FEW METRES INSIDE PADDOCK OF DRIED CEREAL STUBBLE
18/12/91

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
0mE	0.39	20.8	75	
20mE	0.38	20.6	"	
40mE	0.51	20.6	"	Soil firms at depth
60mE	0.62	20.5	"	"
80mE	0.44	20.6	"	"
100mE	0.25	20.8	"	Soil soft all the way
120mE	0.25	20.8	"	"
140mE	0.22	20.8	"	"
160mE	0.38	20.6	"	"
180mE	0.34	20.6	"	"
200mE	0.23	20.9	"	"
220mE	0.24	20.8	"	"
240mE	0.47	20.6	"	"
260mE	0.26	20.8	"	"
280mE	0.25	20.8	"	"
300mE	0.26	20.8	"	"
320mE	0.22	20.8	"	"
340mE	0.23	20.8	"	"
360mE	0.25	20.7	"	Soil v firm below 65 cm
380mE	0.38	20.7	"	Soil firm below 55 cm
400mE	0.49	20.6	"	Soil firm to v firm below 25cm
420mE	0.44	20.6	"	Soil firm below ~60 cm
440mE	0.29	20.7	"	Soil soft all way
460mE	0.23	20.7	"	Soil firm below 70 cm
480mE	0.20	20.8	"	Soil soft all way
500mE	0.23	20.9	"	"
520mE	0.21	20.8	"	"
540mE	0.32	20.7	"	Soil firms bottom few cm
560mE	0.33	20.7	65	Soil hard below 25 cm
580mE	0.35	20.7	75	Soil soft-firm all way
600mE	0.30	20.7	65	Soil hard below ~30 cm

* O_2 air reading = 21.0%

\+ OmE = 35°4.3'N, 139°8.5'E.

TABLE 5

TEPKO ROAD (WESTERN PYRITE HORIZON TRAVERSE NORTH), PADDOCK OF CEREAL STUBBLE WITH RECENT GERMINATION (5-15cm GROWTH)

11/3/92

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
10mE	0.49	20.6	65	Fine sandy topsoil becoming hard at depth
20mE	0.33	20.7	60	" "
30mE	0.36	20.65	65	" "
40mE	0.33	20.7	65	" "
50mE	0.32	20.6	65	" "
60mE	0.31	20.6	65	" "
70mE	0.36	20.6	65	" "
80mE	0.34	20.6	65	" "
90mE	0.28	20.6	65	" "
100mE	0.27	20.6	65	" "

* air reading = 21.0% O_2

TABLE 6

ONKAPARINGA-MURRAY BRIDGE PIPELINE TRAVERSE
WEST OF MONARTO

11/3/92

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments	
10mE	0.40	20.6	50	Dry grass, hard clayey fresh germ. soil	
20mE	0.42	20.5	"	"	"
30mE	0.53	20.45	"	"	Slightly softer
35mE	0.64	20.3	"	"	"
40mE	1.21	19.3	"	"	"
45mE	0.66	20.3	"	"	"
50mE	0.35	20.5	"	"	Hard clayey soil
60mE	0.66	20.2	"	"	"
70mE	0.50	20.2	"	"	"
80mE	0.48	20.4	"	"	"
85mE	0.40	20.5	"	"	"
90mE	1.03	20.0	"	"	"
95mE	0.49	20.5	"	"	"
100mE	0.49	20.6	"	"	"
110mE	0.66	20.45	"	"	"
120mE	0.50	20.5	"	"	"
130mE	0.47	20.5	"	"	"
140mE	0.41	20.6	"	"	"
150mE	0.31	20.5	40	"	+ rock

* air reading = 21.0% O_2

TABLE 7

ACLARE MINE TRAVERSE
FENCE LINE NORTH SIDE OF MINE PADDOCK

19/12/91

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
50mW	0.52	20.6	75	Soil hardens towards bottom
40mW	0.36	20.7	75	" "
30mW	0.29	20.8	75	Soil firm all way
20mW	0.15	20.8	75	Soil hardens towards bottom Hard to pull air
10mW	0.20	20.8	75	Ground firm
OmE	0.32	20.8	75	"
10mE	0.08	20.9	68	Soil hardens towards bottom Hard to pull air
20mE	0.53	20.6	70	" "
30mE	0.05	20.9	42	" "
				Impossible to pull air at 50cm although probe able to penetrate soil
40mE	0.38	20.8	75	Soil firm all way
50mE	0.18	20.8	75	" "
60mE	0.24	20.9	75	Soil fairly soft
70mE	1.27	20.4	75	Creek bed. Ground damp
80mE	0.67	20.5	75	Creek bed. Ground damp

*O_2 air reading = 21.0%

TABLE 8

WHEAL BARTON TRAVERSES
TRAVERSE A, SOUTH OF MAIN SHAFT

10/3/92

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments	
0mE	0.31	20.8	50	Dead grass. New germination	
10mE	0.82	20.5	"	"	"
20mE	0.75	20.5	"	"	"
30mE	0.51	20.5	"	"	"
40mE	0.64	20.4	"	"	"
50mE	0.43	20.7	"	"	"
55mE	0.65	20.4	"	"	"
60mE	0.62	20.3	"	"	"
65mE	0.54	20.5	"	"	"
70mE	0.41	20.6	"	"	"
75mE	0.36	20.7	"	"	"
80mE	0.80	20.3	"	"	"
85mE	0.71	20.3	"	"	"
90mE	0.78	20.2	"	"	"
95mE	0.76	20.2	"	"	"
100mE	0.62	20.5	"	"	"
105mE	0.59	20.5	"	"	"
110mE	0.70	20.3	"	"	"
115mE	0.83	20.2	"	"	"
120mE	0.77	20.3	"	"	"
125mE	0.41	NR	"	"	"
130mE	0.53	20.4	"	"	"
135mE	0.76	20.2	"	"	"
140mE	0.74	20.2	"	"	"
150mE	0.58	20.4	"	"	"
160mE	0.53	20.4	"	"	"
170mE	0.50	20.5	"	"	"
180mE	0.58	20.5	"	"	"
190mE	0.57	20.4	"	"	"
200mE	0.73	20.3	"	"	"

*0_2 air reading = 21.0%

TABLE 9

WHEAL BARTON TRAVERSES
TRAVERSE B BETWEEN THE TWO NORTH SHAFTS

10/3/92

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
6mE		Claim post - SW corner		
10mE	0.32	20.6	50	Dry grass
20mE	0.30	20.8	50	Dry grass 7m from gum trees
22.5mE	0.68	20.3	50	Dry grass 3m from gum tree
25mE	1.17	19.9	50	Dry grass 7m from gum trees
26.7mE	0.49	20.4	50	
30mE	0.43	20.5	45	Sparse dry grass
35mE	0.50	20.6	50	"
36mE	Intersection with line between two shafts			
40mE	0.36	20.6	50	8m high gum tree 2.5 m away
45mE	0.33	20.6	50	Sparse dry grass
50mE	0.39	20.6	50	"
60mE	0.32	20.7	50	"
70mE	0.32	20.5	50	"

*0_2 air reading = 21.0%

TABLE 10

KANAPPA MINE AREA - SANDERSON
TRAVERSE ACROSS STRIKE OF LIMONITIC LIMESTONE

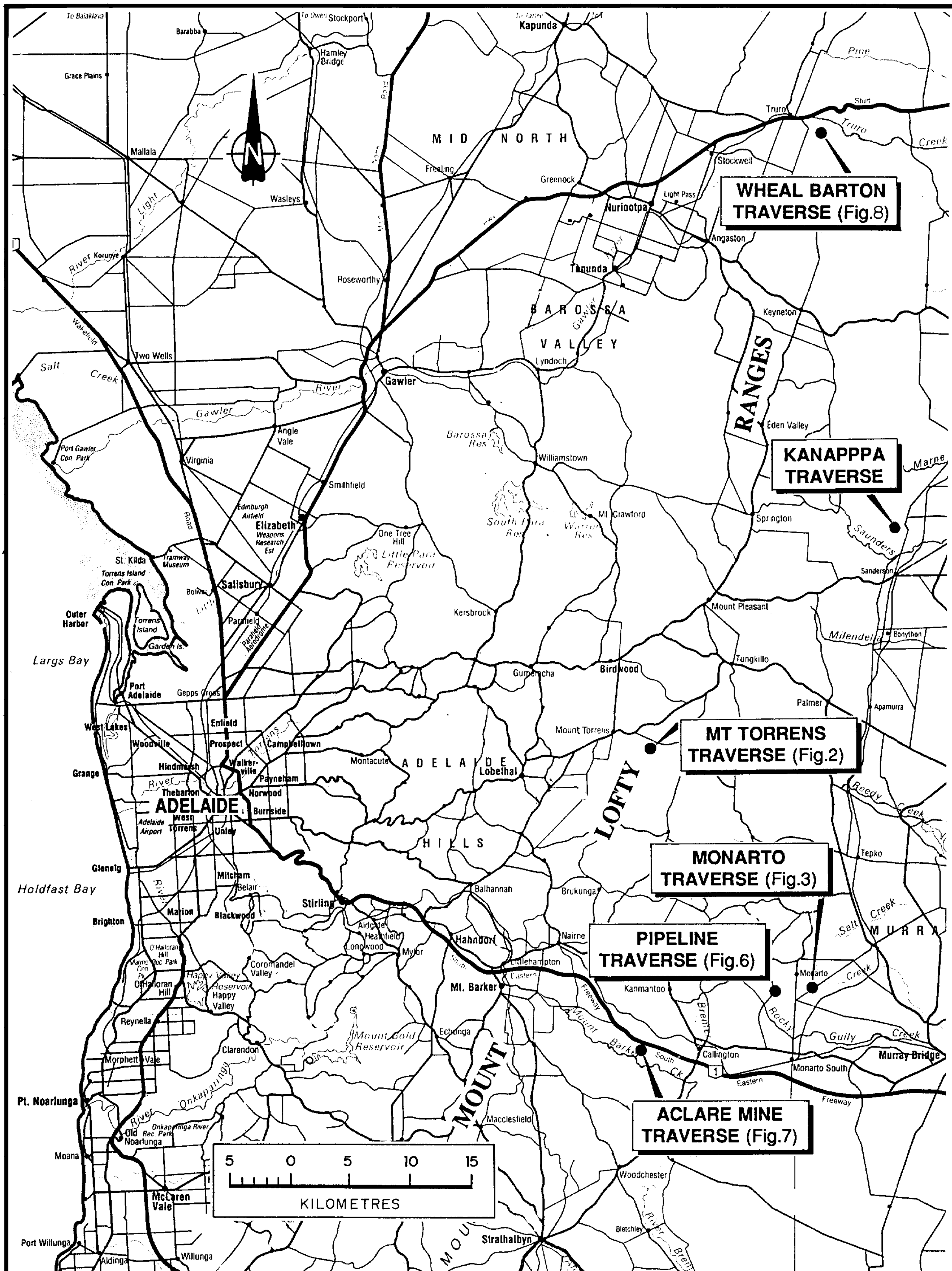
11/3/92

Coordinates	CO_2%	O_2%*	Depth (cm)	Comments
44mW	0.20	20.9	42	Dry grass. New germination up to a few cm
40mW	0.32	20.8	55	"
35mW	0.16	20.8	50	"
30mW	0.14	20.8	50	"
25mW	0.22	20.8	50	"
20mW	0.27	20.65	50	"
15mW	0.27	20.6	50	"
10mW	0.19	20.7	75	"
10mW	0.18	20.8	50	"
1mW	0.15	20.7	50	"
10mE	0.14	20.8	50	" Cereal paddock

*0_2 air reading = 21.0%
OmE = north-south fence line

APPENDIX

Ground Magnetic Profiles



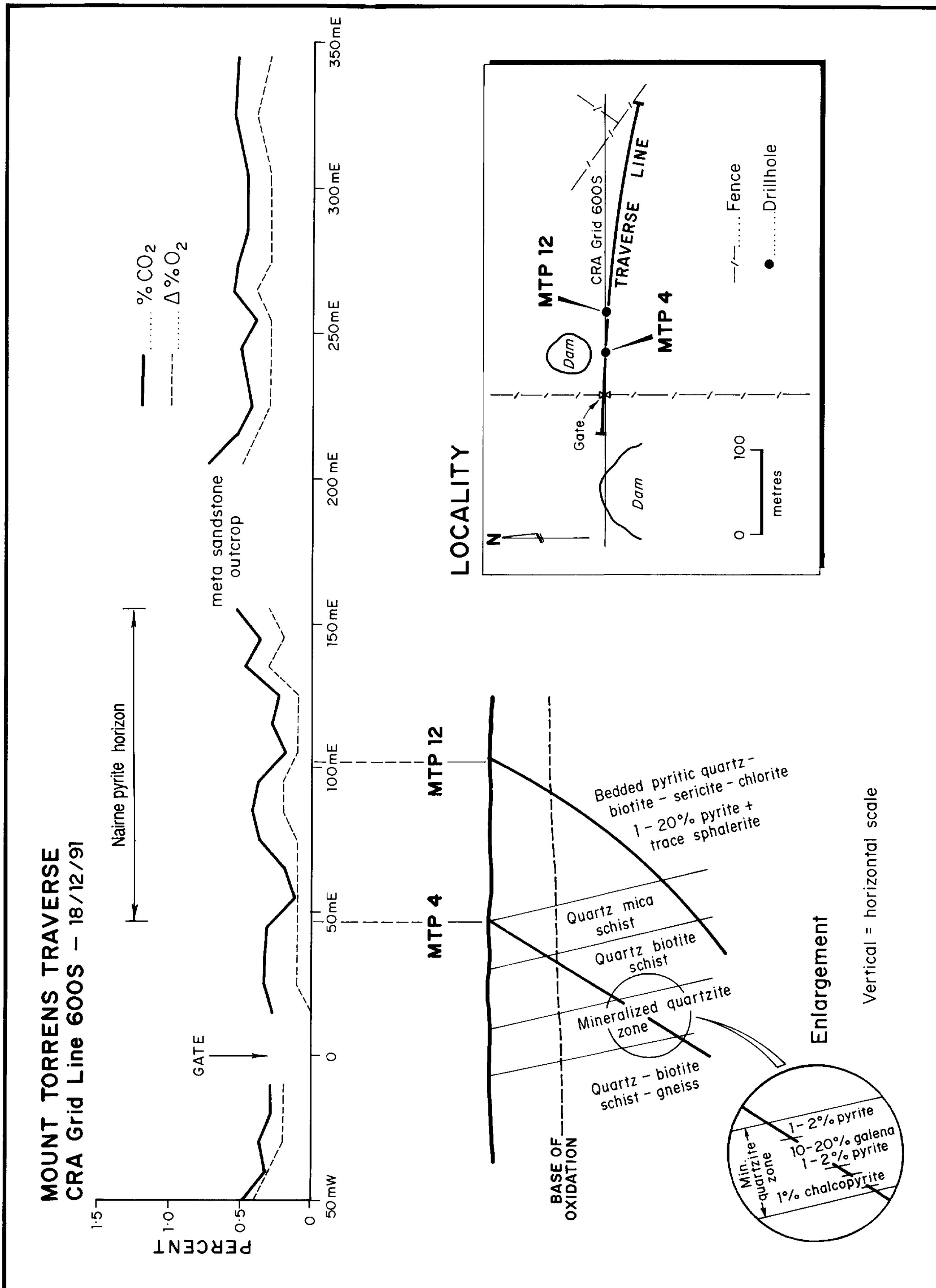
SOIL AIR CO_2 and O_2 SURVEY

MOUNT LOFTY RANGES

LOCALITY PLAN

Figure 1

SADME 92-464

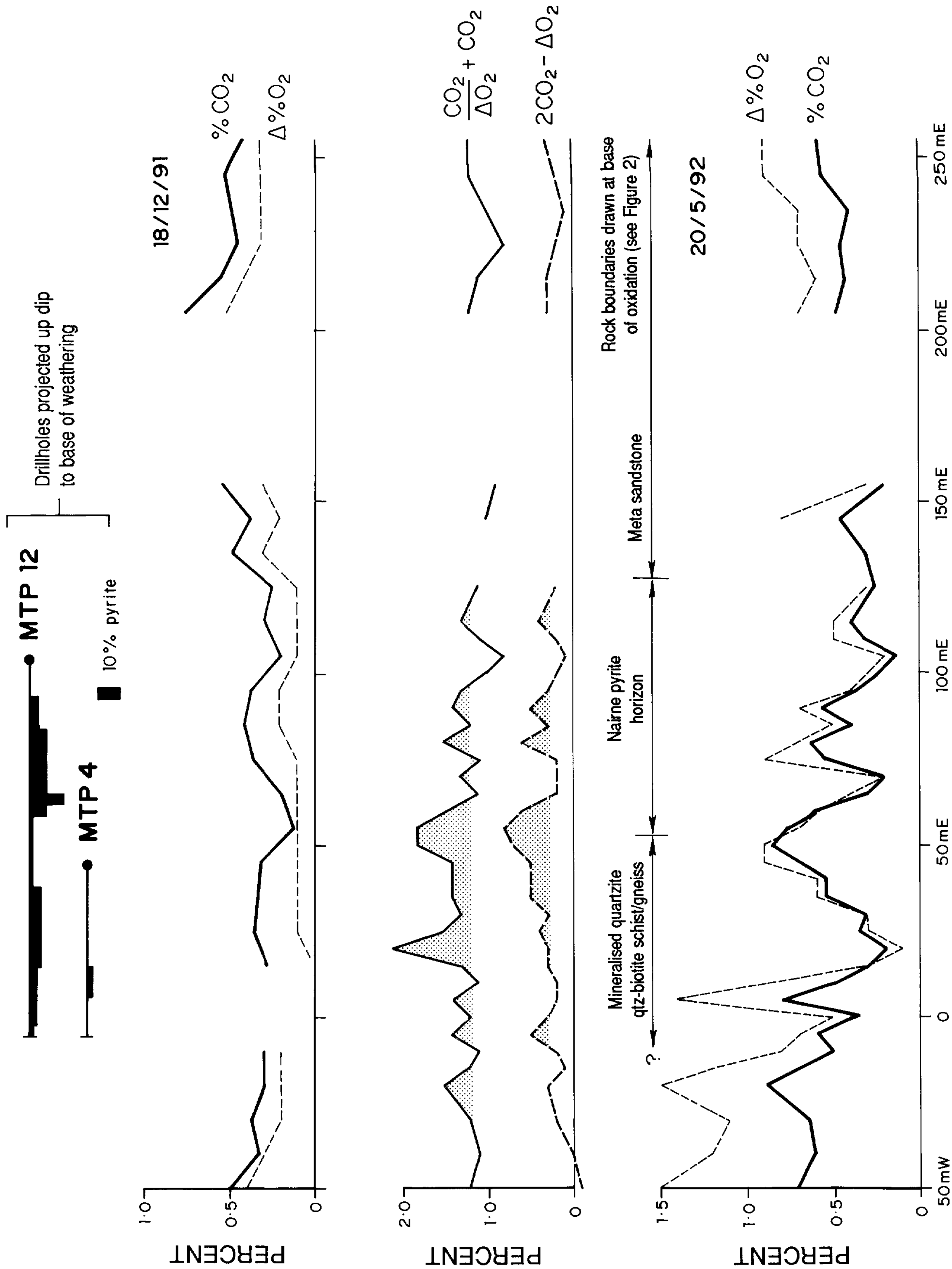


SOIL AIR CO_2 and O_2 SURVEY
MOUNT LOFTY RANGES

MOUNT TORRENS TRAVERSE

Figure **2A**
SADME 92-465

5621



SOIL AIR CO_2 and O_2 SURVEY

MOUNT LOFTY RANGES

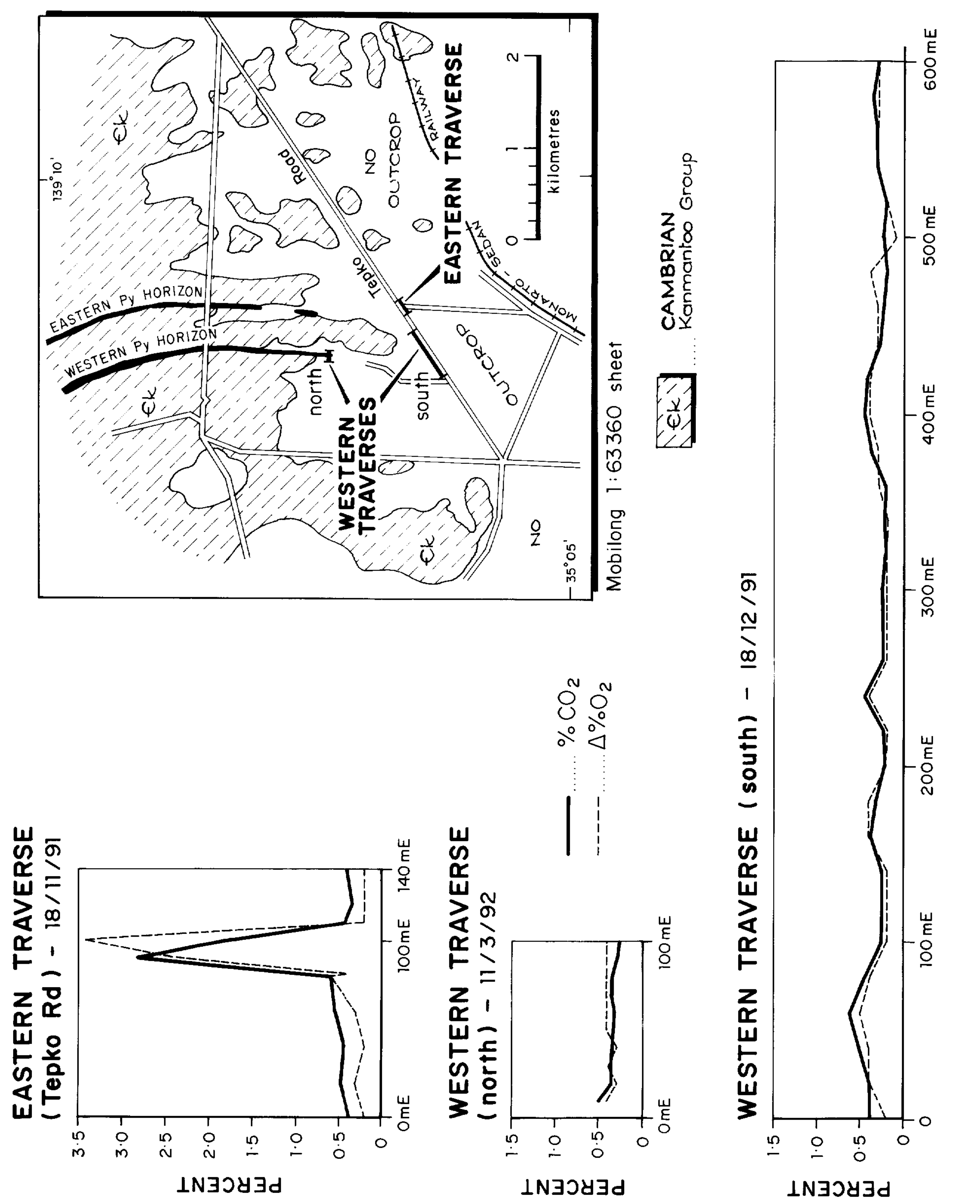
MOUNT TORRENS TRAVERSE

(Comparison of December and May surveys)

Figure **2B**

SADME 92-635

5621



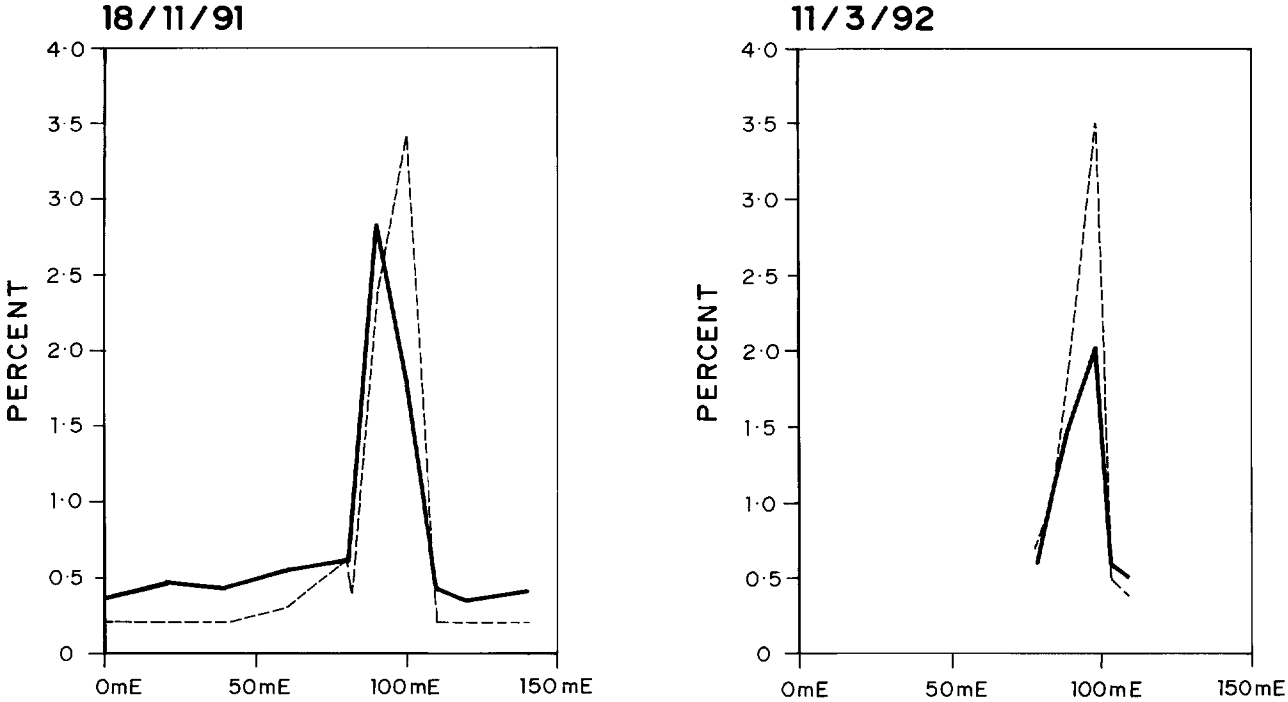
SOIL AIR CO_2 and O_2 SURVEY

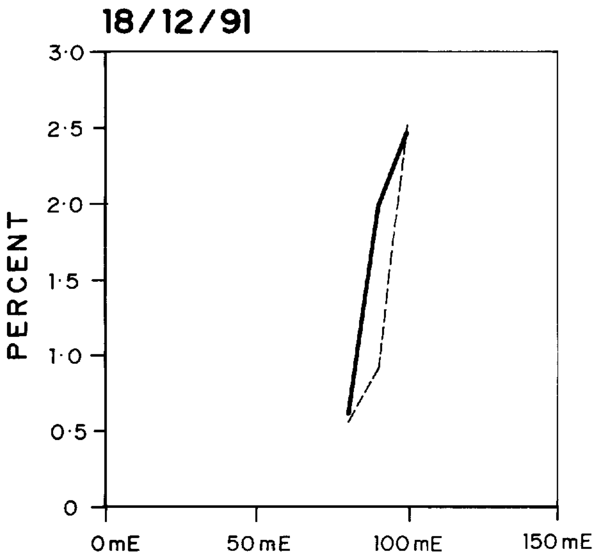
MOUNT LOFTY RANGES

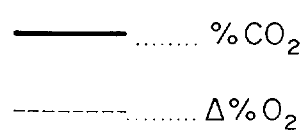
MONARTO TRAVERSE (Tepko Rd)

Figure **3**

SADME 92-466







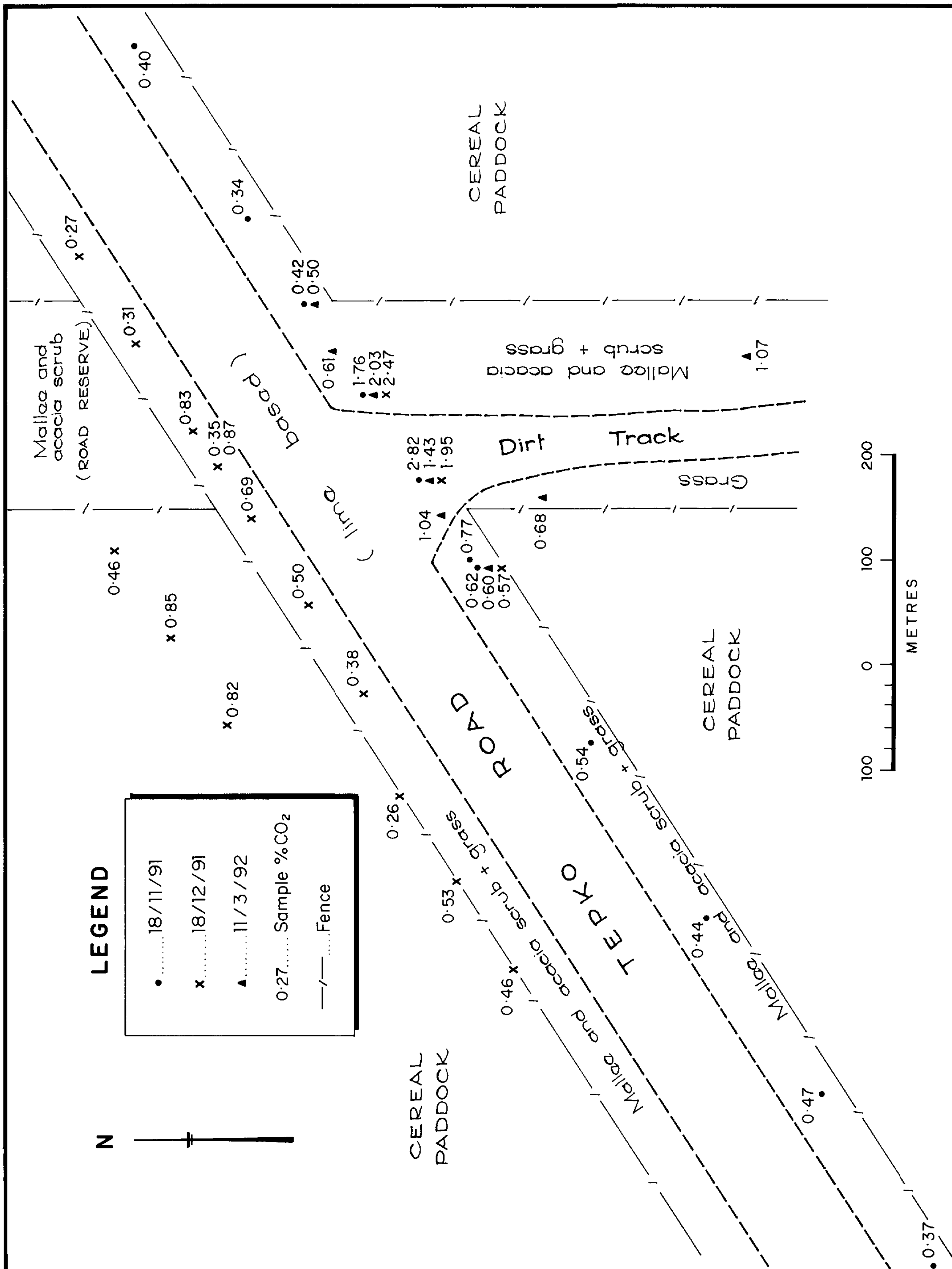
NOTE: For location of traverse see Figure 3 (plan no. 92-466)

SOIL AIR CO_2 and O_2 SURVEY
MOUNT LOFTY RANGES

MONARTO TRAVERSE
(Eastern Pyritic Horizon Anomaly)

Figure **4**
SADME 92-467

5621



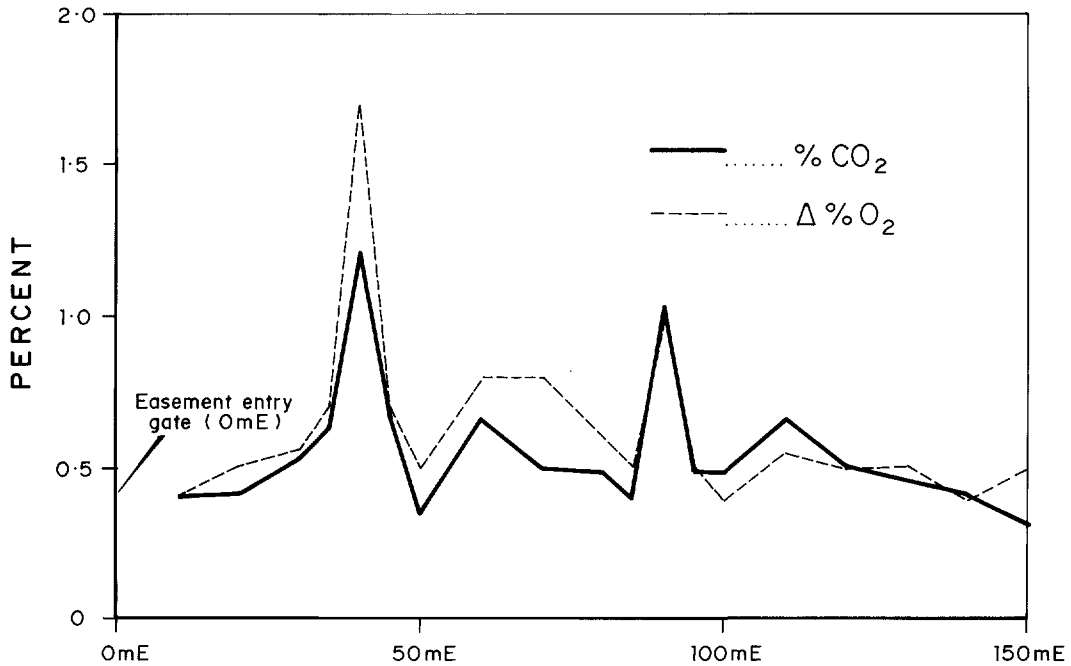
SOIL AIR CO_2 and O_2 SURVEY
MOUNT LOFTY RANGES

MONARTO TRAVERSE - Soil CO_2 values
(Eastern Pyritic Horizon Anomaly)

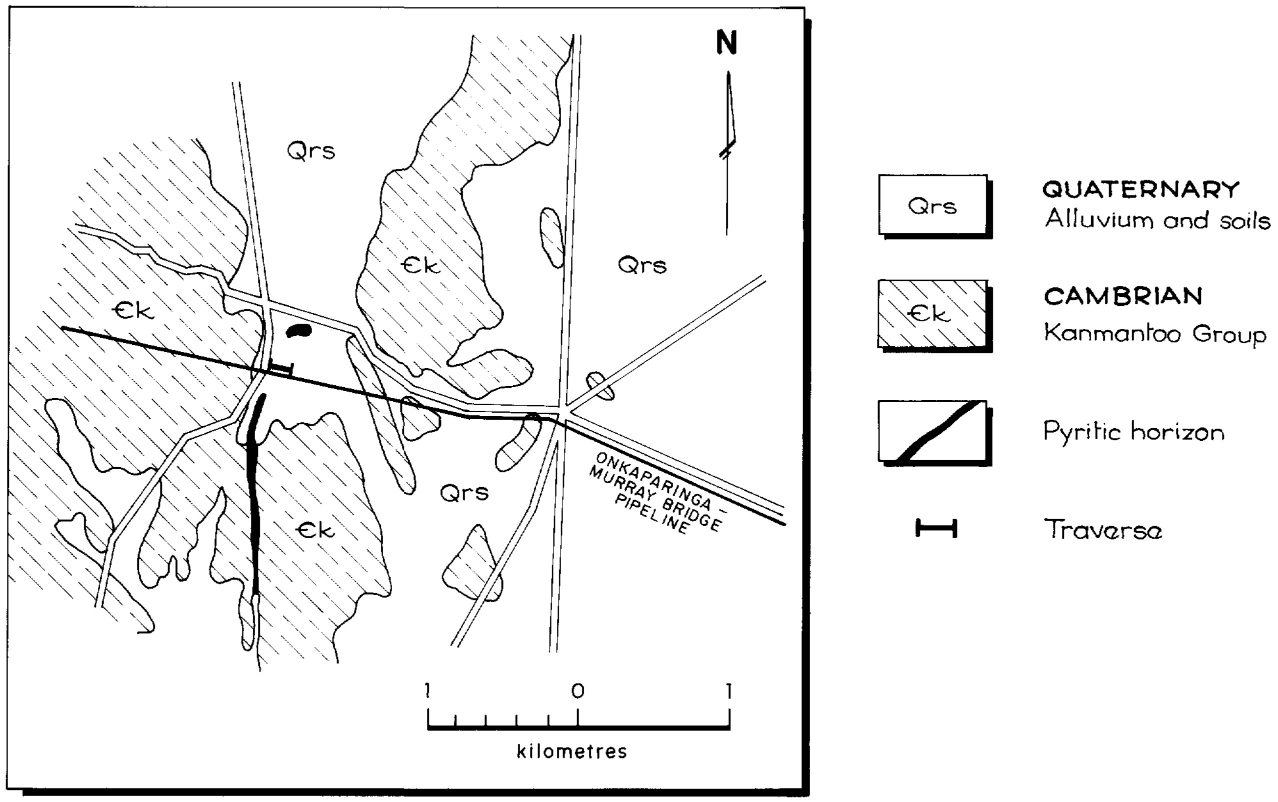
Figure **5**
SADME 92-468

5621

PIPELINE TRAVERSE – 11/3/92



LOCALITY

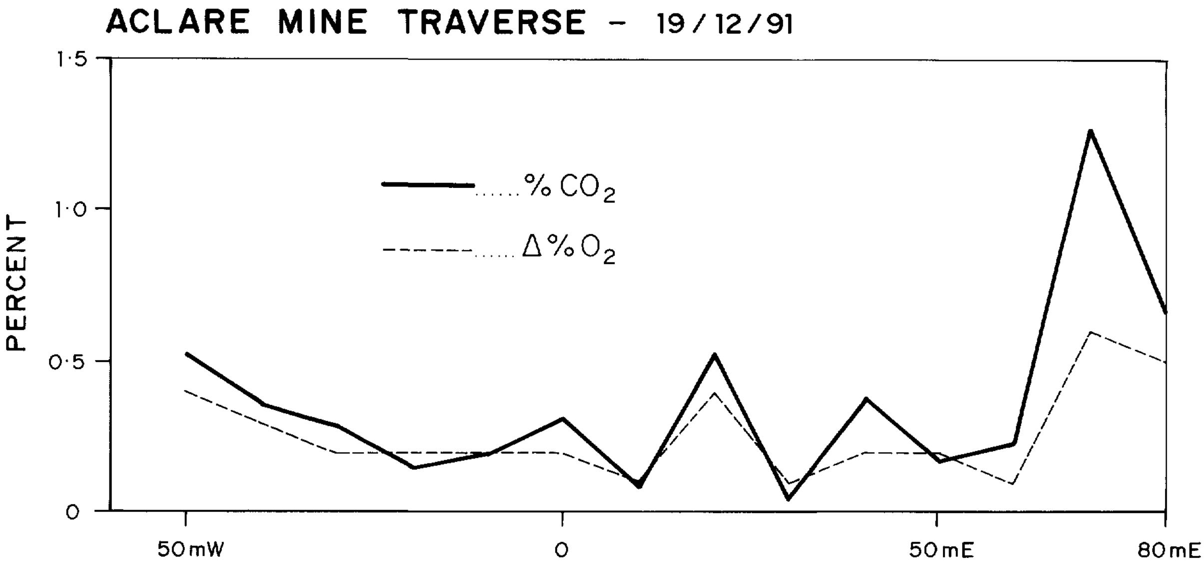


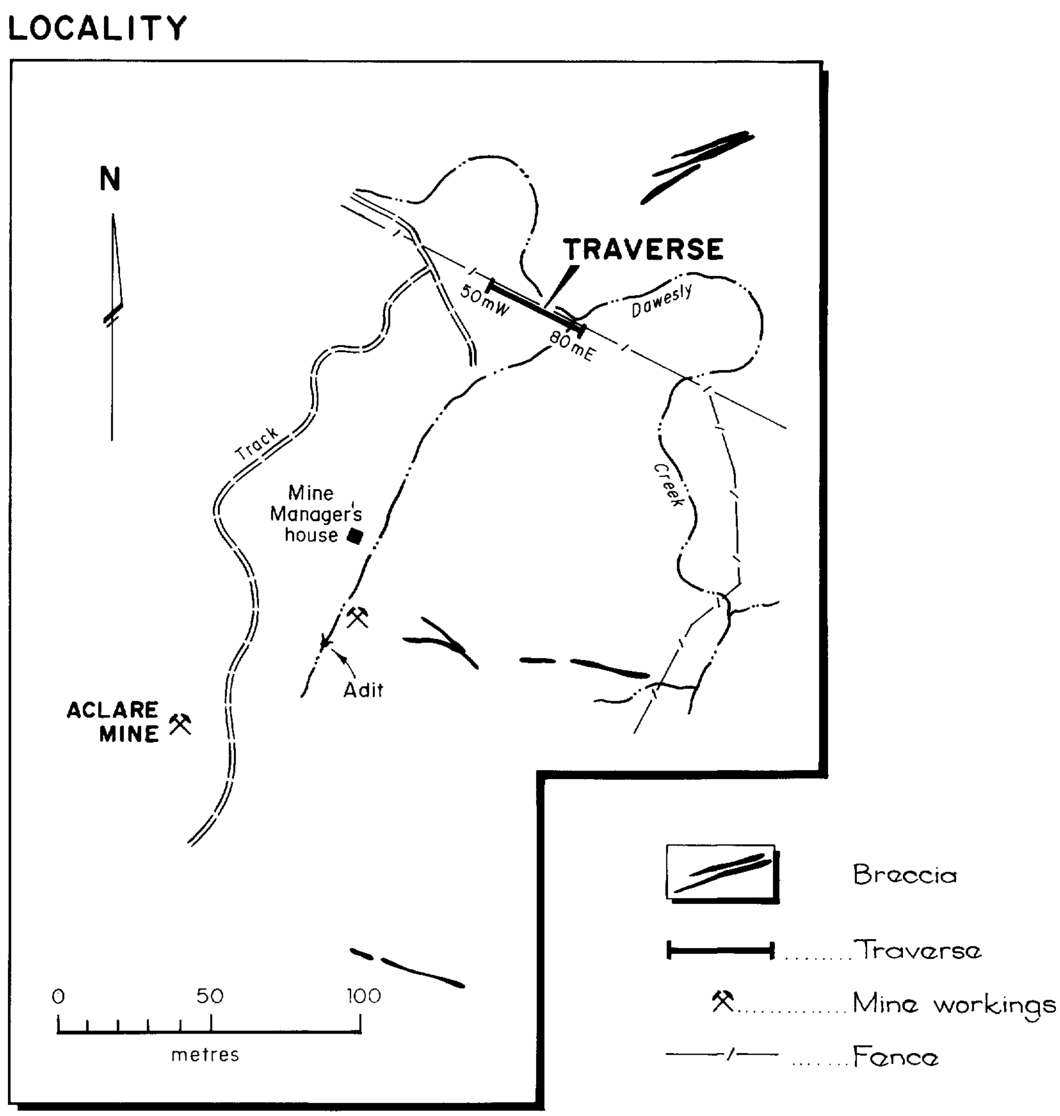
Geology from Mobilong 1 : 63 360 sheet

SOIL AIR CO_2 and O_2 SURVEY
MOUNT LOFTY RANGES

MONARTO PIPELINE TRAVERSE

Figure **6**
SADME 92-469

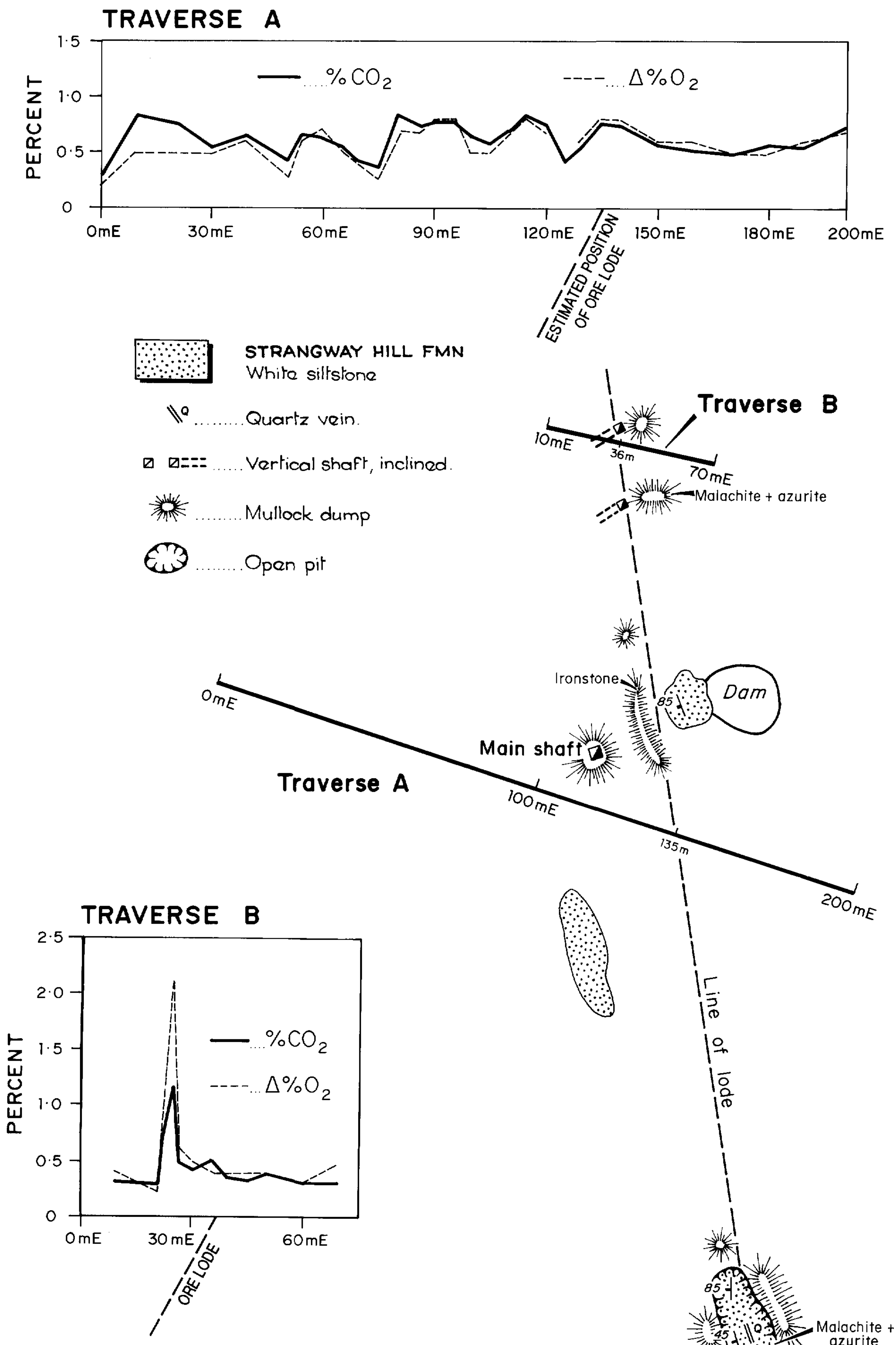




SOIL AIR CO_2 and O_2 SURVEY
MOUNT LOFTY RANGES
ACLARE MINE TRAVERSE

Figure **7**
SADME 92-470

5621



SOIL AIR CO_2 and O_2 SURVEY
MOUNT LOFTY RANGES
WHEAL BARTON TRAVERSE

Figure 8
SADME 92-471