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LITHOGEOCHEMISTRY OF ROCK CHIP SAMPLES
FROM EXPLORATION TRENCHING
LARA PROJECT, VANCOUVER ISLAND, BRITISH COLUMBIA

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by
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1. Introduction

The 1983 Lara trench sampling program consisted of a systematic study of major and trace element patterns in wallrocks found to enclose mineralized horizons. The purpose of this study was to firstly identify, on a broad scale, areas which appeared to best typify regional alteration halos, as previously defined by workers in similar geological environments. Based on results of the regional examination, the second purpose of this study was to define, in detail, areas which should receive a closer geological and geophysical examination.

Composite rock chip samples were obtained from each field identifiable rock unit, with no one composite representing more than 5 m of exposed section. Selected samples from mineralized horizons were kept separate from unmineralized wallrocks. With the exception of the initial trenches, only samples immediately surrounding visible mineralization were analyzed for the major elements Na_2O, CaO, K_2O and MgO, however, most samples had the trace elements Cu, Pb, Zn, Ag, Mn, As and Ba determined routinely. Au was analyzed in the majority of samples.

All analyses were performed by Bondar-Clegg Ltd. of Vancouver. The major elements plus As and Ba were determined using XRF techniques; Cu, Pb, Zn, Mn and Ag were detected from acid solution using atomic absorption; and Au was analyzed using a combination fire assay-atomic absorption method.

2. Interpretation Criteria

Numerous geochemical studies of trace and major element signatures in wallrock associated with volcanogenic sulphide deposits were compiled. Table I (adapted from Govett, 1983) presents the distillation of these signatures and includes an estimation of anomaly size as well as constituents.

Examination of Table I reveals several patterns that are common to nearly all exhalative deposits regardless of ore forming components, age, or stratigraphic position. Mg and Cu are enriched near the ore bodies relative to similar rocks more distant from the mineralized horizon, while Na and Ca are almost universally depleted in concentration.

Detailed examination of these deposits has shown both hangingwall and footwall rocks to be enriched in Mg, while Mn, Cu, and Na often are enriched in hangingwall and depleted in footwall rocks. Other elements, not listed in the table, have been shown to be useful indicators of proximity to hydrothermal activity. As is usually enriched in footwall rocks, while Ba and Au are commonly enriched in hangingwall rocks (Sangster, Personal Communication).

These patterns of enrichment and depletion have led to the use of element ratios in an attempt to enhance the contrast between "anomalous" and "background" values. The most common ratios include MgO/Na_2O, MgO/CaO and K_2O/Na_2O, the latter ratio often being ambiguous. Studies of the Kuroko deposits have utilized the ratio $(K_2O+MgO)x100$ / $K_2O+Na_2O+CaO+MgO$ termed the "Alteration Index" (Ishikawa et al, 1976), which incorporates most of the major elements. Kalogeropoulos and Scott (1983) found this ratio to increase from 50 to 90 percent at the Fukazawa deposit over a distance of about 2 km.

TABLE 1

Summary of Characteristic Geochemical Responses Around Volcanogenic Massive Sulphide Deposits

Mineralization	Mine	Cu	Mn	Ba	Na	K	Ca	Mg	Dimensions
Zn-Cu	Millenbach				-	±	-	+	>200 m
Zn-Cu-Pb	Mattabi	+	+		-		-	(+)	400-800 m
Zn-Cu	Fox	+			-	±	-		100-250 m
Zn-Cu	Jay				-			+	500 m
Cu-Pb-Zn	Hanson	+							60 m
Zn-Cu	East Waite	+	+		-		-	+	600 m
Zn-Cu	South Bay				-		-	+	100 m
Cu-Zn	Norbec		+		-		-	+	450-700 m
Cu	Louvem				-		-	+	200-400 m
Zn-Cu	Detour					-		-	200 m
Cu	Boliden, Outer				-		-	+	>300 m
	Boliden, Inner				-	+	-	-	
Zn-Pb-Cu	Brunswick 12	±	±		-	±	-	+	450x915 m
Zn-Pb-Cu	Heath Steele	+	±		-	+	-	+	100x>1140 m
Zn-Pb-Cu	Caribou	+	+		+	-	-	+	200x800 m
Zn-Pb-Cu	Key Anacon	+			-	+	-	+	205x1800 m
Zn-Pb-Cu	Woodlawn				-	-	-	+	400-800 m
Cu	Prince Lyell	+	+	+	-	+	-	+	>300x700 m
Zn-Cu-Pb	East Tuva		+	+					100 m
Cu-Zn-Pb	Kuroko			+	-	+	±	+	1000 m
Zn-Cu	Wainaleka	+			-	-	-	+	300-1200 m

Detailed Geochemical Response

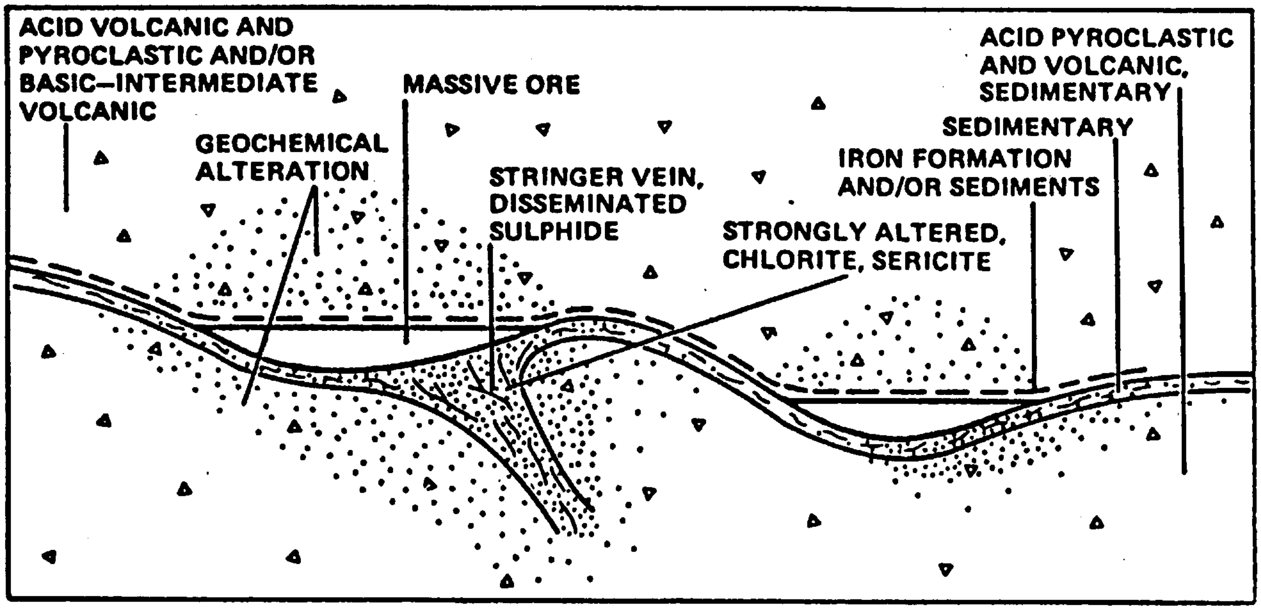
Mineralization	Mine	Stratigraphy	Cu	Mn	Ba	Na	K	Ca	Mg
Zn-Cu	Millenbach	FW				-	-	-	+
Zn-Cu-Pb	Mattabi	FW	+	+		-		-	+
Zn-Cu	Fox	HW	+			+	-	-	
		FW	+			-	+	-	
Cu-Zn-Pb	Kuroko	HW				-		+	+
		FW	+	-		-	+	-	+
Zn-Pb-Cu	Brunswick 12	HW	-	-					
		FW	+	-					
Zn-Cu	Wainaleka	HW	+	+		+			
		FW	+	-		-		-	+

+	=	enrichment
-	=	depletion
±	=	enrichment and depletion in different parts of halo.

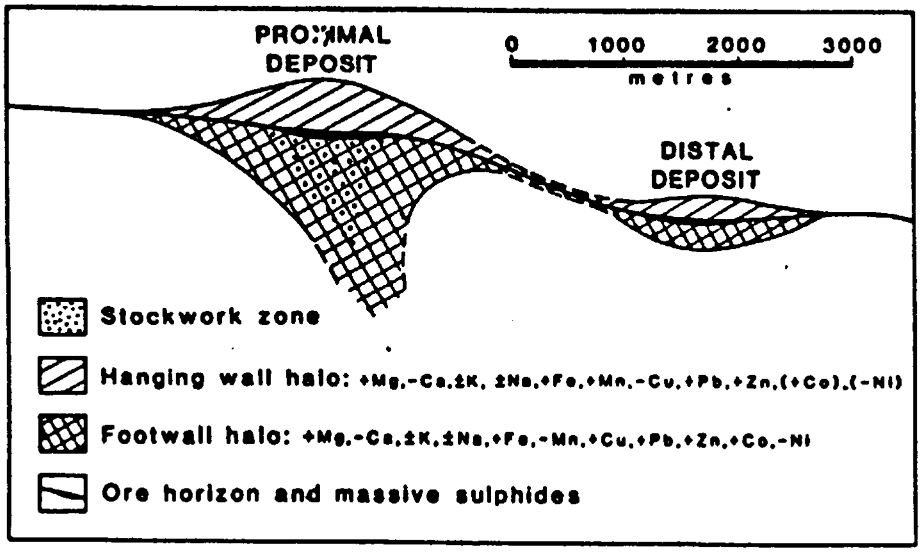
The Lara property is underlain in part by acidic volcanic and pyroclastic rocks known to be favourable hosts for sulphide mineralization. In addition, the property is located in close proximity to the Mt. Sicker massive sulphide mineralization. This geological environment can result in mineralization both proximal and distal to a vent source, as shown in Figures 1 a and b.

Geochemical halos enclosing a proximal deposit located within or above a vent usually extend well into both footwall and hangingwall and are intense and pervasive. Metalliferous brines originating from a vent may flow along the sea floor and accumulate in areas of depression, resulting in a distal deposit. Wallrock halos associated with either solution pathways or distal deposits are typically restricted to the immediate vicinity of the mineralization, and when present, lack intensity. In most cases, the bulk chemistry of the wallrocks is not significantly altered, although the concentration of ore forming elements may increase significantly.

Although hydrothermally induced alteration is an overprint on preexisting rock types, the chemical patterns resulting from alteration will depend to a large extent on the original composition of those host rocks. Several lithogeochemical studies have shown that an alteration signature can be greatly enhanced by comparing the chemistry of different rock types on a common basis. A popular method of comparison is to ratio the chemical elements being examined to a standard SiO_2 content. This approach requires a complete rock analysis for each sample, and is usually beyond the budgetary constraints of a mineral exploration program.


ACID VOLCANIC AND PYROCLASTIC AND/OR BASIC–INTERMEDIATE VOLCANIC
GEOCHEMICAL ALTERATION
MASSIVE ORE
STRINGER VEIN, DISSEMINATED SULPHIDE
STRONGLY ALTERED, CHLORITE, SERICITE
IRON FORMATION AND/OR SEDIMENTS
SEDIMENTARY
ACID PYROCLASTIC AND VOLCANIC, SEDIMENTARY

a)


PROXIMAL DEPOSIT
0
1000
2000
3000
metres
DISTAL DEPOSIT
Stockwork zone
Hanging wall halo: +Mg,-Ca,±K, ±Na,+Fe,+Mn,-Cu,+Pb,+Zn,(+Co),(-Ni)
Footwall halo: +Mg,-Ca,±K,±Na,+Fe,-Mn,+Cu,+Pb,+Zn,+Co,-Ni
Ore horizon and massive sulphides

b)

Figure 1

The standardization approach taken in this study was to separate each of the major rock-forming or lattice substituting elements according to the rock field name. A separate mean and standard deviation for each element was calculated for each rock type, and a threshold value, defined as the mean ± one standard deviation, was then assigned to each category. Interpretational preference was given to the distribution of the threshold values of certain elements rather than mean values because both positive and negative extremes can occur in hydrothermally altered rock; the mean value may not change appreciably. A high standard deviation in rock forming elements is usually indicative of some type of chemical activity, even though a consistent pattern may not be apparent. Elements studied in detail include Na_2O, CaO, MgO, As and Zn. The ratios of MgO/Na_2O, $MgOxCu/CaOxNa_2O$ and $MgOx10/CaOxNa_2O$ were also calculated but only the latter ratio was plotted. The Alteration Index R, was calculated for all rocks on a trench-by-trench basis and the mean value for each trench plotted, as shown in Figures 5 and 11.

3. Results

3.1 Regional Comparisons

Major and minor elements in samples from the east and west grids were statistically separated, then compared, in a first pass attempt at determining a direction to increasing alteration. Major element comparisons are shown in Table 2 and trace elements in Table 3.

The mean Na_2O content of the rhyolitic rocks is significantly lower on the east grid compared to the west grid, however the reverse is true for the more intermediate andesitic rocks on the west grid. The west grid Na_2O threshold values in acidic rocks show a significantly wider range than on the east grid; usually indicative of the presence of some form of chemical rearrangement. There is little to choose between the two areas based on Na_2O content alone.

MgO concentrations and threshold values in rhyolites are somewhat higher on the west grid than on the east grid. The more intermediate rocks, especially the andesites, contain a higher concentration of MgO on the east grid and also show a wider range of values. The MgO/Na_2O ratio indicates that there is little difference between the east and west grid rhyolites but significant differences exist in dacites and andesites with the more altered rocks occurring on the east grid.

The pattern shown by K_2O is similar to Na_2O in that the spread of values in rhyolites is higher on the west grid, however the spread is significantly reduced in more intermediate rocks. K_2O in itself is not a definitive indicator of hydrothermal alteration, but the above patterns suggest that rhyolites on the west grid may be somewhat more chemically altered compared to the east grid, but that the intermediate rocks on the east grid are significantly more altered than those on the west.

The most distintive chemical difference between east and west grid rocks is shown by CaO. All three rock types from the east grid are significantly depleted in CaO and all show a wide range of concentrations. Intermediate rocks are depleted more strongly than are the acidic rocks.

The strong CaO depletion is the major contributor to the element ratio patterns calculated for samples from the two grids. The two major element ratios shown in Table 2 are higher on the east grid than on the west grid for all rock types; the highest contrast being in the intermediate rocks. The average alteration index "R" shown at the bottom of Table 2 is significantly higher on the east grid than on the west grid, with values above 80% being common. A value near 70% or higher was found for rocks within 1 km of the Fukazawa deposit (Kalogeropoulous and Scott, 1983), while values near 50% were considered to be background.

Except for As and Zn, the average trace element concentrations presented in Table 3 do not show appreciable differences between the east and west grids; Zn is higher in all rocks from the east grid and the main concentration of As in all trenches from the east grid is nearly three times higher than on the west grid.

In summary, major and trace element data to date indicate that rocks from the east grid show a higher degree of "typical" hydrothermal alteration than rocks obtained from the west grid. However, data from the west grid is widely spaced and does not represent a comprehensive test.

TABLE 2

Comparison of Major Elements and Their Ratios in East Grid and West Grid Rock Samples

Rock Type	Element	East Grid Mean	East Grid Threshold		West Grid Mean	West Grid Threshold	
			High	Low		High	Low
Rhyolite	Na_2O	1.52	2.49	.55	2.44	4.54	.34
	MgO	1.61	2.62		2.71	4.96	
	MgO/Na_2O	1.51	2.83		1.68	3.25	
	K_2O	3.63	4.82	2.44	1.73	3.76	-
	CaO	.58	1.45	-	1.81	2.76	.83
	$\frac{\text{MgOx10}}{\text{CaOxNa}_2\text{O}}$	31	58		12	28	
	$\frac{\text{MgOxCu}}{\text{CaOxNa}_2\text{O}}$	332	852		125	351	
Dacite	Na_2O	1.40	2.07	.73	2.51	3.15	1.87
	MgO	5.19	6.81		4.27	5.81	
	MgO/Na_2O	3.77	5.67		1.88	2.87	
	K_2O	3.04	4.95	1.13	1.68	2.28	1.08
	CaO	1.05	2.36	-	2.83	4.23	1.45
	$\frac{\text{MgOx10}}{\text{CaOxNa}_2\text{O}}$	38	69		10	20	
	$\frac{\text{MgOxCu}}{\text{CaOxNa}_2\text{O}}$	887	1806		362	768	
Andesite	Na_2O	2.31	3.26	1.36	1.94	2.72	1.16
	MgO	6.34	8.22		5.19	5.57	
	MgO/Na_2O	3.87	6.16		2.40	3.03	
	K_2O	1.25	2.81	-	1.14	1.65	.63
	CaO	1.96	3.30	.62	4.07	5.37	2.77
	$\frac{\text{MgOx10}}{\text{CaOxNa}_2\text{O}}$	27	53		7.6	10	
	$\frac{\text{MgOxCu}}{\text{CaOxNa}_2\text{O}}$	783	2069		340	592	
All Rocks	R	67.0			54.9		

TABLE 3

Comparison of Trace Elements in East Grid and West Grid Rock Samples

Rock Type	Element	East Grid Mean	East Grid Threshold		West Grid Mean	West Grid Threshold	
			High	Low		High	Low
Rhyolite	Cu	48	103		53	108	
	Zn	76	145		49	75	
	Mn	482	762	202	444	682	206
	Ba	1829	3178		1672	3209	
Dacite	Cu	86	153		90	148	
	Zn	150	273		78	116	
	Mn	1162	1798	526	943	1297	589
	Ba	1578	2538		1475	2612	
Andesite	Cu	130	241		136	196	
	Zn	101	181		83	121	
	Mn	1205	1500	910	956	1366	546
	Ba	811	2198		1050	1952	
All Rocks	As	11	23		4.4	6.2	

3.2 Detailed Comparisons

Subsequent to dividing the trench lithogeochemistry into east and west grid data sets, each of these two areas were examined individually to determine which of the newly discovered mineralized horizons is associated with wallrock alteration. In addition, where the density of sampling permitted, a locus for the most intense alteration within each horizon was estimated.

The results of this interpretation are presented as cartoons of the east and west grid areas. The northern and southern mineralized horizons on the east grid, presented in Figures 2 to 7, are shown separately. Asterisks are plotted at the position of significant sulphide mineralization beside each discovery trench. Trenches are plotted to scale relative with one another, however the spatial separation between the two mineralized horizons has been compressed in order to facilitate convenient presentation. A similar compression of scale has been done between the three mineralized horizons on the west grid, shown in Figures 8-13.

Each diagram presents two forms of interpretation for each element or element ratio with the exception of As and the Alteration Index. The average concentration of a variable for each trench, regardless of rock type, is plotted beside the trench and reveals some indication of the overall chemical pattern both within a mineralized horizon, and between different horizons. Elements and element ratios were separated according to rock type for the purpose of performing a statistical analysis, as previously described. Zones of anomalous element or element ratios, corrected for rock type, are shown by solid bars within each trench. The position of chemically altered rock regardless of rock type, relative to the mineralized horizon, can easily be seen.

3.2.1 East Grid

The major elements Na_2O and CaO in rocks from the east grid trenches are shown in Figures 2 and 3. Both elements are strongly depeleted in the lower mineralized horizon relative to the upper horizon. The average concentration of Na_2O is lowest in Trench 19A and CaO is lowest in the adjacent Trench 20. The strongest continuous rock anomalies also occur in these two trenches. There appears to be little evidence of wallrock element depletion associated with the upper mineralized horizon, except for rocks immediately surrounding mineralization in Trench 29. Major element analysis in Trench 29 did not extend appreciably beyond the mineralized zone.

Two major element ratios are shown in Figures 4 and 5. These ratios definitively indicate that the wallrock surrounding mineralization in the lower horizon has been hydrothermally altered; the centre of this alteration being near Trenches 19A and 20. An Alteration Index of >85% is found in several Kuroko deposits within 200 m of economic mineralization (Kalogeropoulos and Scott, 1983). R values exceeding 85% are common in rocks from the lower mineralized horizon.

Patterns of the trace elements Zn and As in wallrocks correlate well with those of the major elements in that the concentrations in wallrocks of the lower mineralized horizon are significantly enhanced. The average Zn concentration is highest in Trench 19A, while the average As content in Trench 20 is an order of magnitude greater than that found in the upper mineralized horizon. As is usually confined to the higher temperature core of a mineralizing event, therefore, the high As concentration in Trench 20 should correlate with the highest alteration signature. Comparison of As with the two major element ratios confirms this correlation.

Several inferences regarding the structure of the lower mineralized horizon can be attempted by examining the major and trace element data. Historical data and logic dictate that in a near source hydrothermal system, footwall rocks should be more highly altered than are hangingwall rocks. Data from the lower mineralized horizon suggests that footwall is to the north in Trenches 20, 19A and 23, but is to the south in Trench 25. In addition, field geological data indicated that the lower mineralized horizon was disrupted by a fault or fault wedge near or in Trench 21. The complete absence of a geochemical signature in Trench 21 similar to surrounding rocks supports this interpretation.

In summary, the lower mineralized horizon on the east grid is interpreted as being formed in close proximity to a source of hydrothermal solutions. The area closest to source is presently defined by Trenches 19A and 20. Current literature suggests that the source of solutions should lie within 200 m of Trenches 19A and 20.

3.2.2 West Grid

Mineralized intersections on the west grid are presently interpreted as occurring in three distinct horizons, comprising the intersections found in Trenches 31 and 32, Trench 34, and Trenches 35 and 36. None of the intersections exhibit as strong an alteration signature as is found on the east grid, therefore the present samples are interpreted as reflecting an environment more distal from a source of heat than do the samples from the east grid. The major elements Na_2O and CaO are plotted in Figures 8 and 9. The upper mineralized horizon exhibits a slight decrease in both elements in Trench 31 compared to Trench 32. The two element ratios, plotted in Figures 10 and 11 show a corresponding increase in values to the west. Although the evidence is scanty, these two patterns, coupled with positive soil geochemistry, indicate that trenching and sampling should be continued to the west.

Comparisons of the wallrock chemical signature in Trench 34 with that in Trench 35 indicate that the most altered of these two horizons is around the Trench 34 mineralization. Although the main concentration of Na_2O is the same in both trenches, the anomaly is more widely distributed in Trench 34. There is a distinct CaO depletion in the rocks of Trench 34 compared to other west grid samples, and the two ratios are considerably higher. Comparisons of the strength of the Alteration Index with distance from the Fukazawa deposits show that values of 70-75% were found within 1 km of the ore body (Kalogeropoulos and Scott, 1983). The pausity of data on the west grid does not permit the interpretation to extend to geological structure or direction to source.

The two trace elements, Zn and As, are plotted in Figures 12 and 13 respectively. Zn is clearly anomalous in Trench 34 compared to other west grid trenches. As, however, is extremely high in Trench 35. Visible arsenopyrite associated with calcite veins was noted in the trench. Both As and calcite are not in character with an apparently unaltered volcanic pile, therefore, this occurrence is interpreted as being associated with a mineralized shear rather than a stratiform horizon. As associated with volcanic rocks in Trench 34 is therefore considerably higher than in other west grid trenches, although not nearly the order of magnitude found on the east grid.

To summarize, the west grid mineralized horizons are not associated with distinct and pervasive wallrock alteration and are therefore considered to represent one or more mineralizing events which occurred at the same stratigraphic horizon but some distance from the location of the west grid trenches. Of the trenches sampled, Trench 34 appears to contain wallrock which best typifies a hydrothermal alteration halo. Trenches 31 and 32 present some evidence to suggest the direction to increasing heat and hopefully additional mineralization is to the west.

4. Recommendations

4.1 East Grid

1) The lower mineralized horizon should be explored in detail. Deep penetrating EM, such as a MAXMIN or EM-37, should be placed on 50 m lines from Line 29 to Line 37. Resulting anomalies should be drilled. If no EM responses are found, the area to the north of Trench 20 should be drilled anyway. Down-the-hole EM could be contemplated should this occur. Additional surface work could include further trenching between Trench 20 and Trench 25, although the lack of a surface geochemical expression on Line 33 may indicate a structural dislocation of the mineralized horizon such as was found near Trench 21. Geochemical analysis for major and trace elements on all rocks should continue.

2) Exploration should continue to the west on the upper mineralized horizon. Additional trenches placed at 50 m intervals from Lines 37 to 41 should be sampled in an attempt to define an alteration halo, and to better understand the geological environment.

4.2 West Grid

1) Deep penetrating EM should be placed over the upper and central mineralized horizons and should be extended to the west along the strike of the surface geochemical anomalies.

2) Trenches 4 and 10, along strike to the west of the Trench 34 mineralization, should be reopened and sampled in detail.

3) EM responses associated with any of the mineralized horizons should be drilled.

4) Shallow drill holes could be placed between Trenches 36 and 33 to test the lower mineralized horizon where overburden is considered to be excessively deep.

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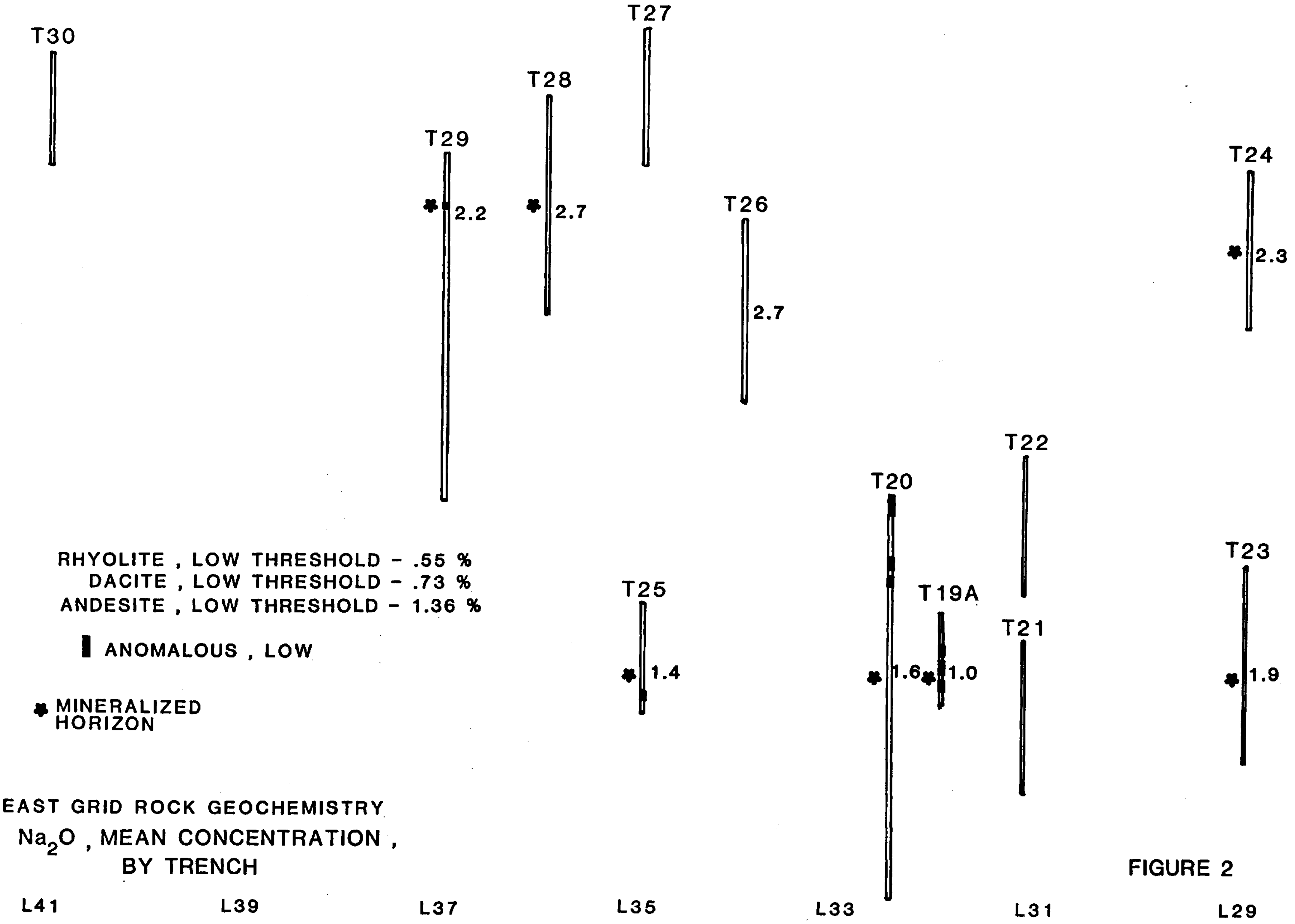
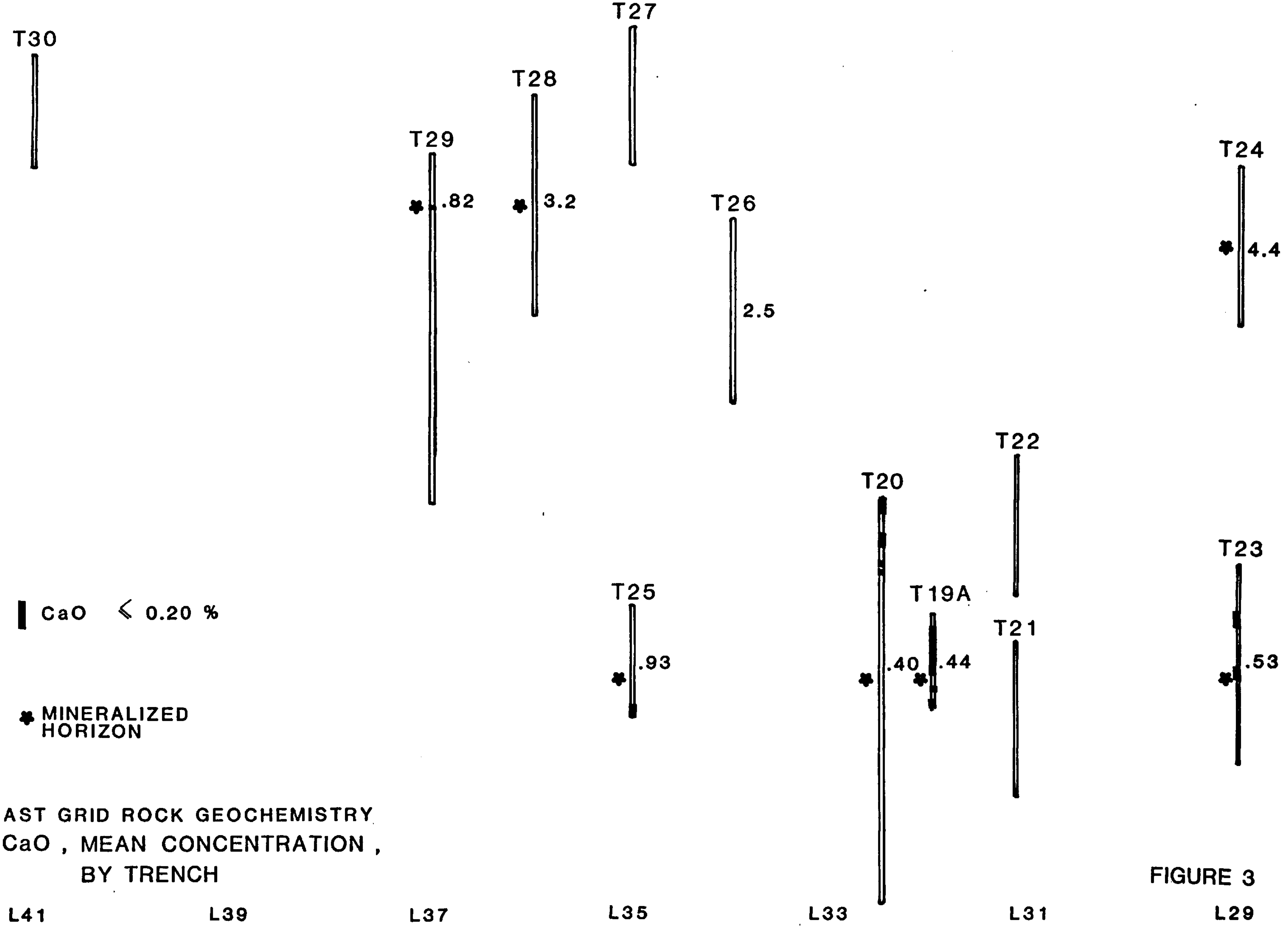


EAST GRID ROCK GEOCHEMISTRY

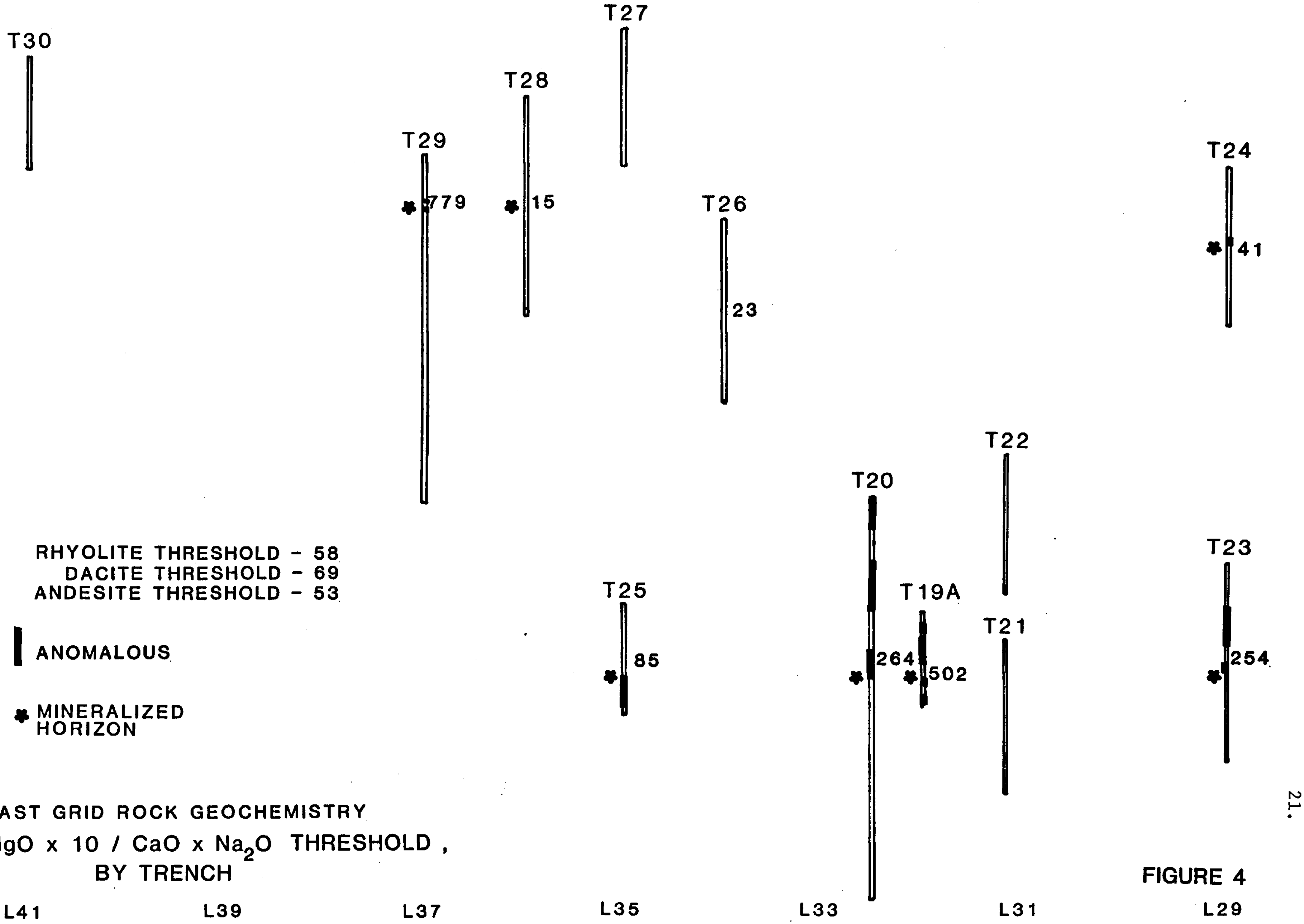
Na_2O , MEAN CONCENTRATION , BY TRENCH

FIGURE 2



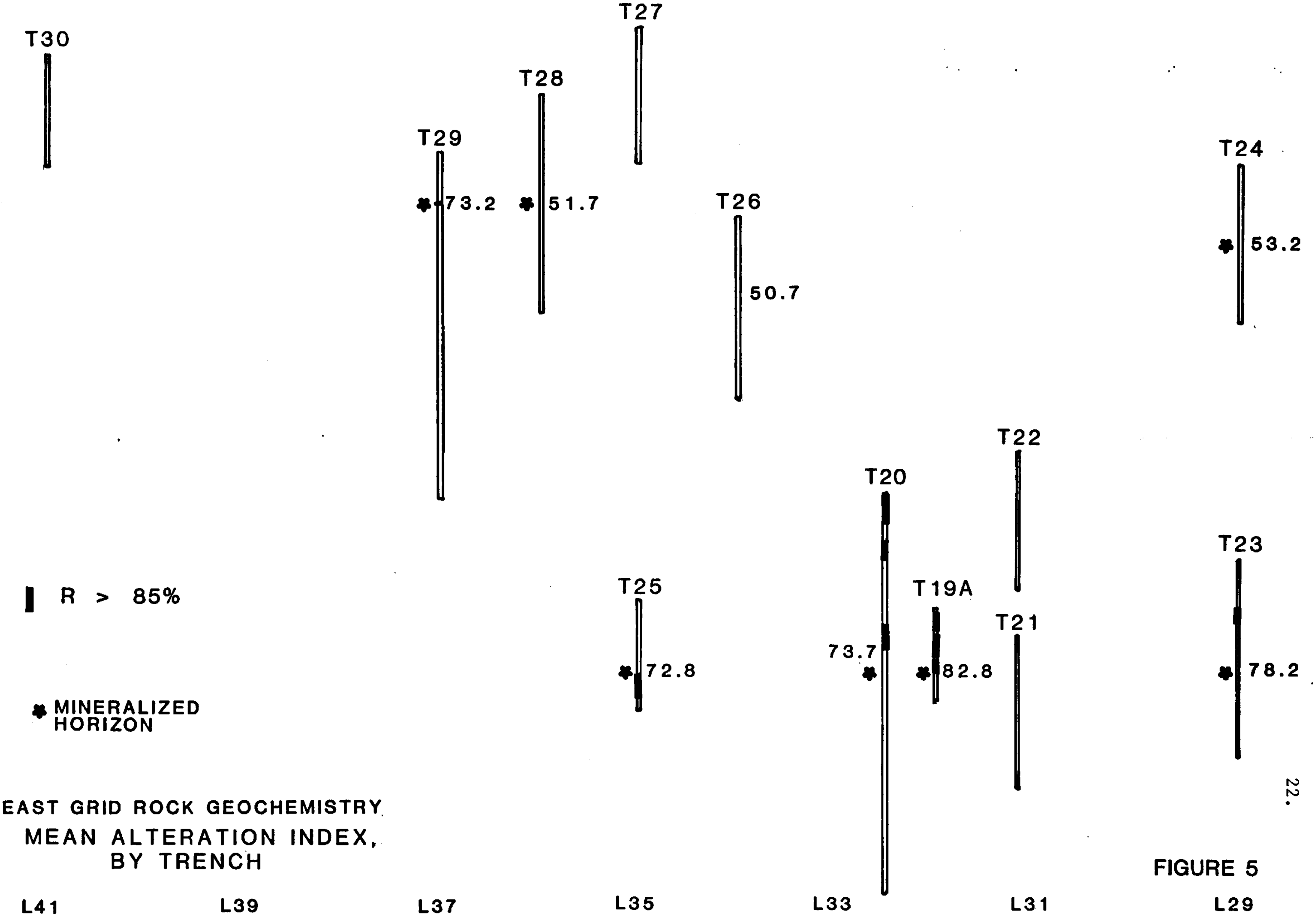
EAST GRID ROCK GEOCHEMISTRY
CaO , MEAN CONCENTRATION ,
BY TRENCH

FIGURE 3



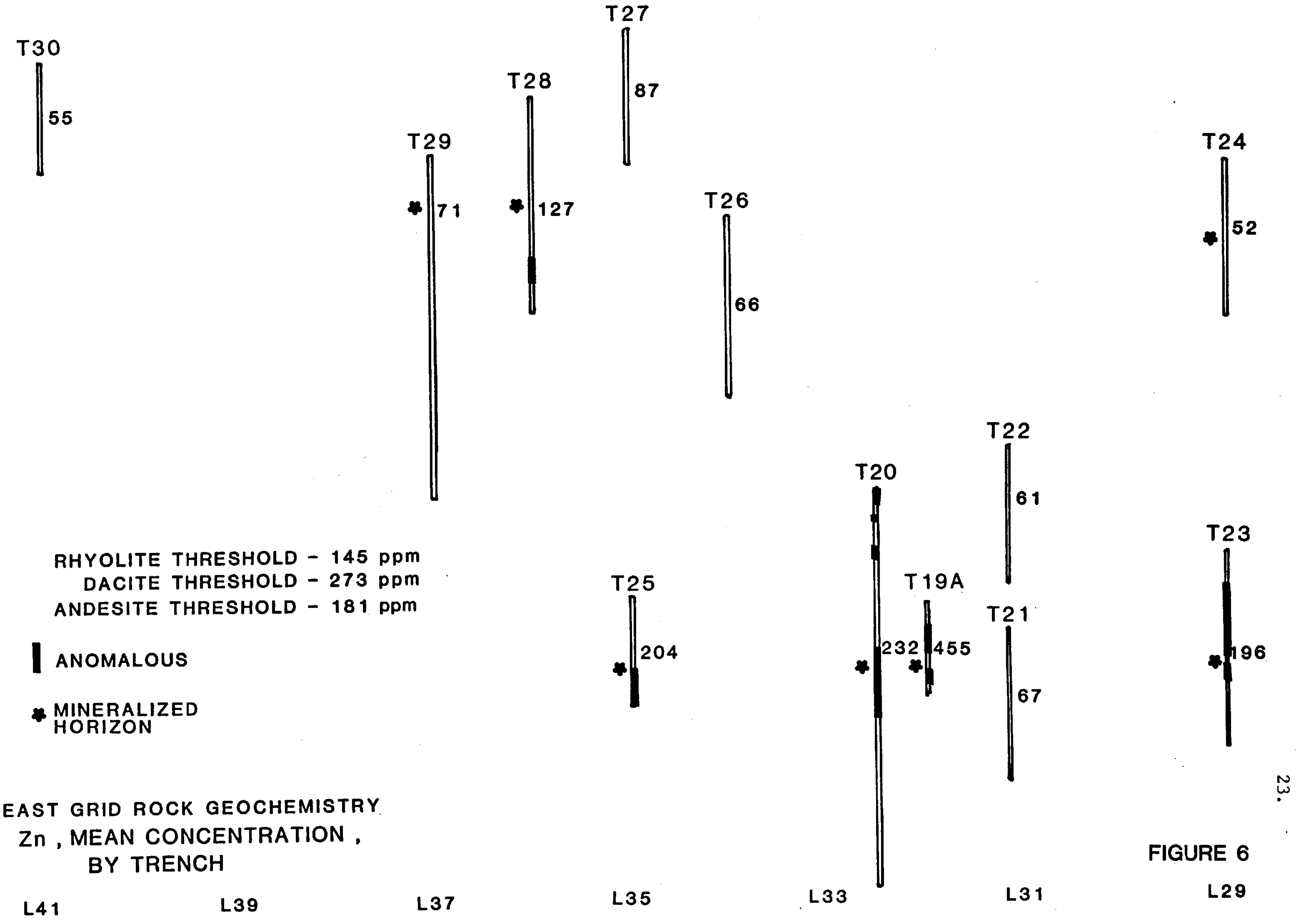
EAST GRID ROCK GEOCHEMISTRY
MgO x 10 / CaO x Na_2O THRESHOLD ,
BY TRENCH

FIGURE 4



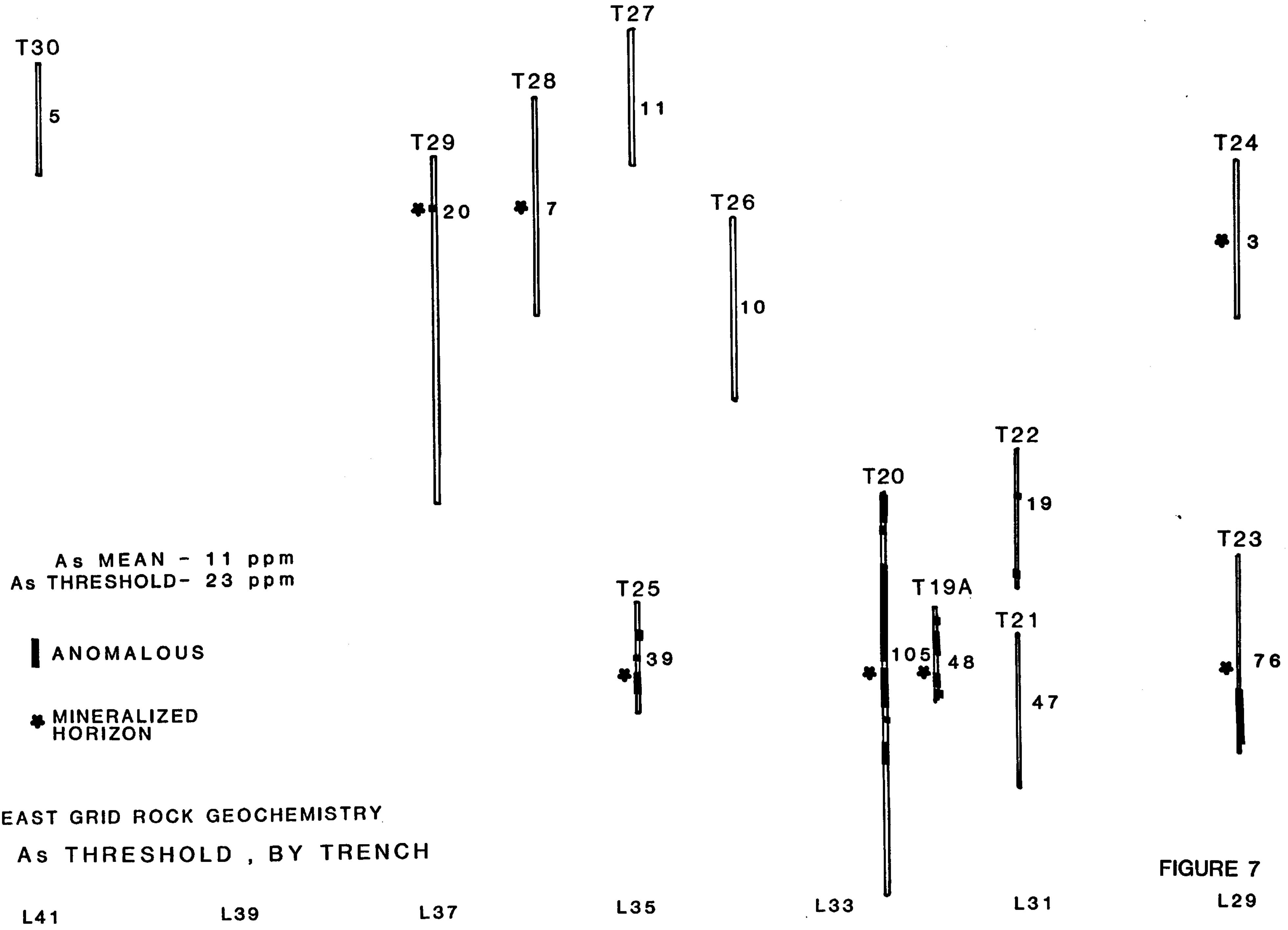
EAST GRID ROCK GEOCHEMISTRY
MEAN ALTERATION INDEX,
BY TRENCH

FIGURE 5



EAST GRID ROCK GEOCHEMISTRY
Zn , MEAN CONCENTRATION ,
BY TRENCH

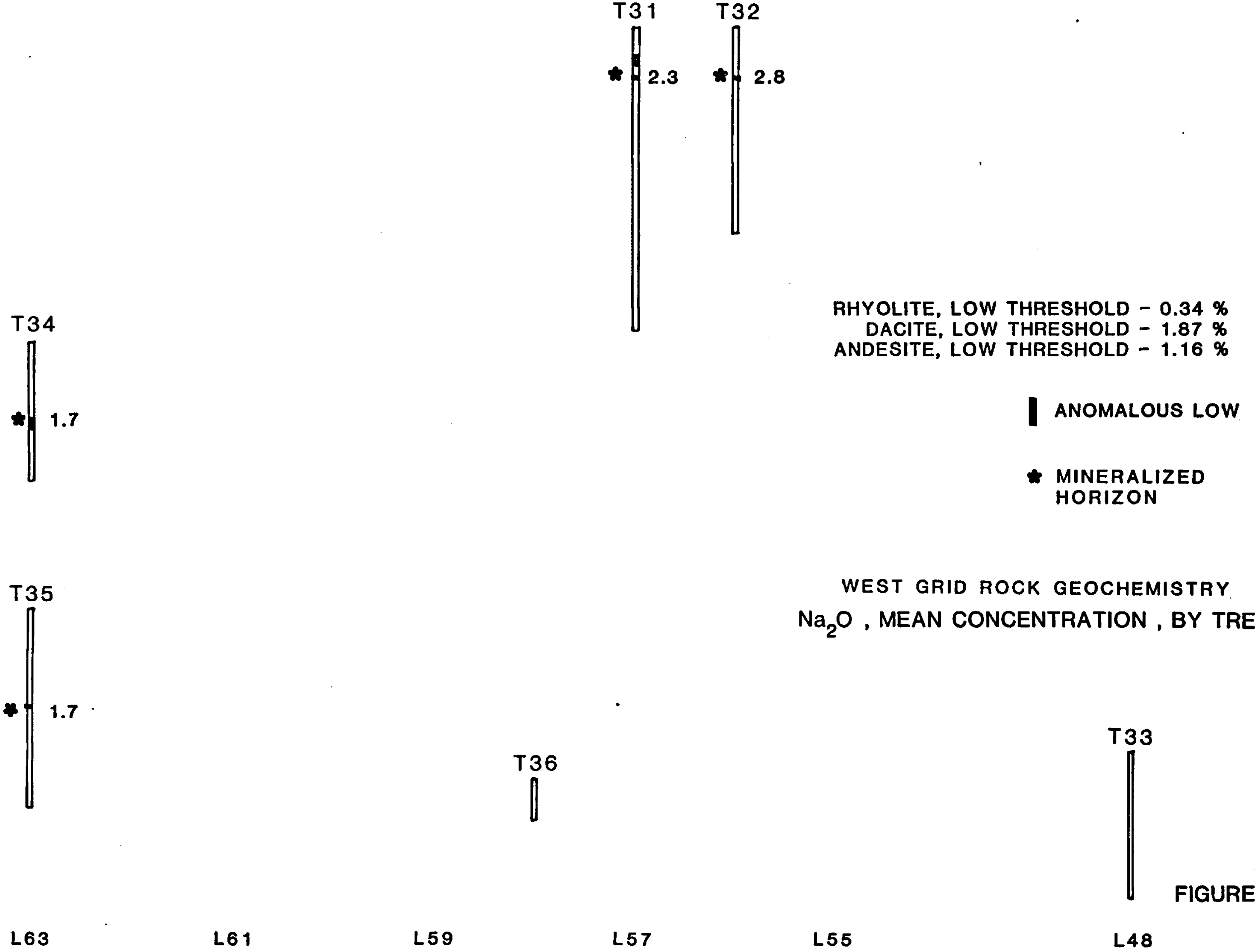
FIGURE 6



EAST GRID ROCK GEOCHEMISTRY

As THRESHOLD, BY TRENCH

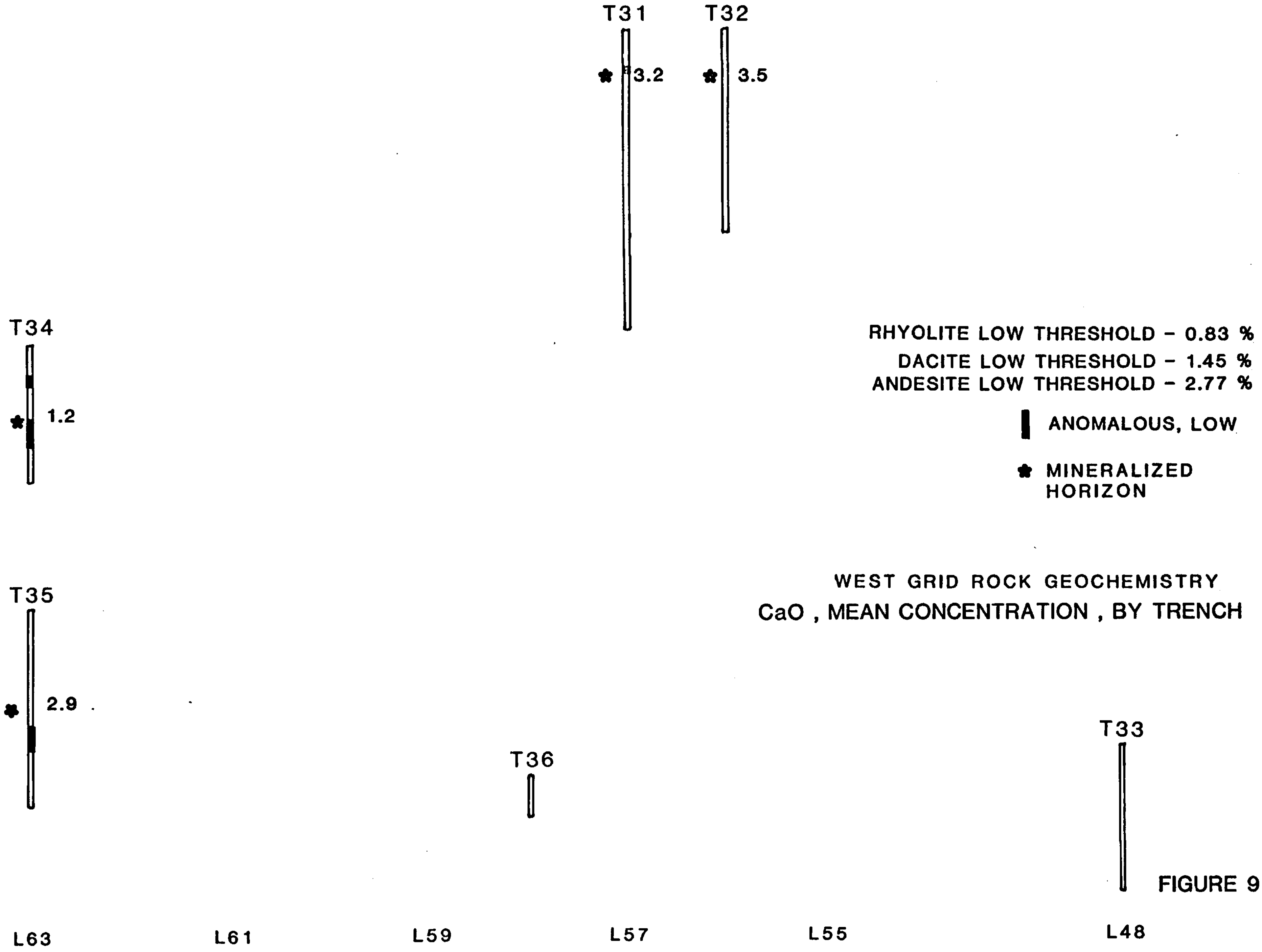
FIGURE 7



WEST GRID ROCK GEOCHEMISTRY

Na_2O , MEAN CONCENTRATION , BY TRENCH

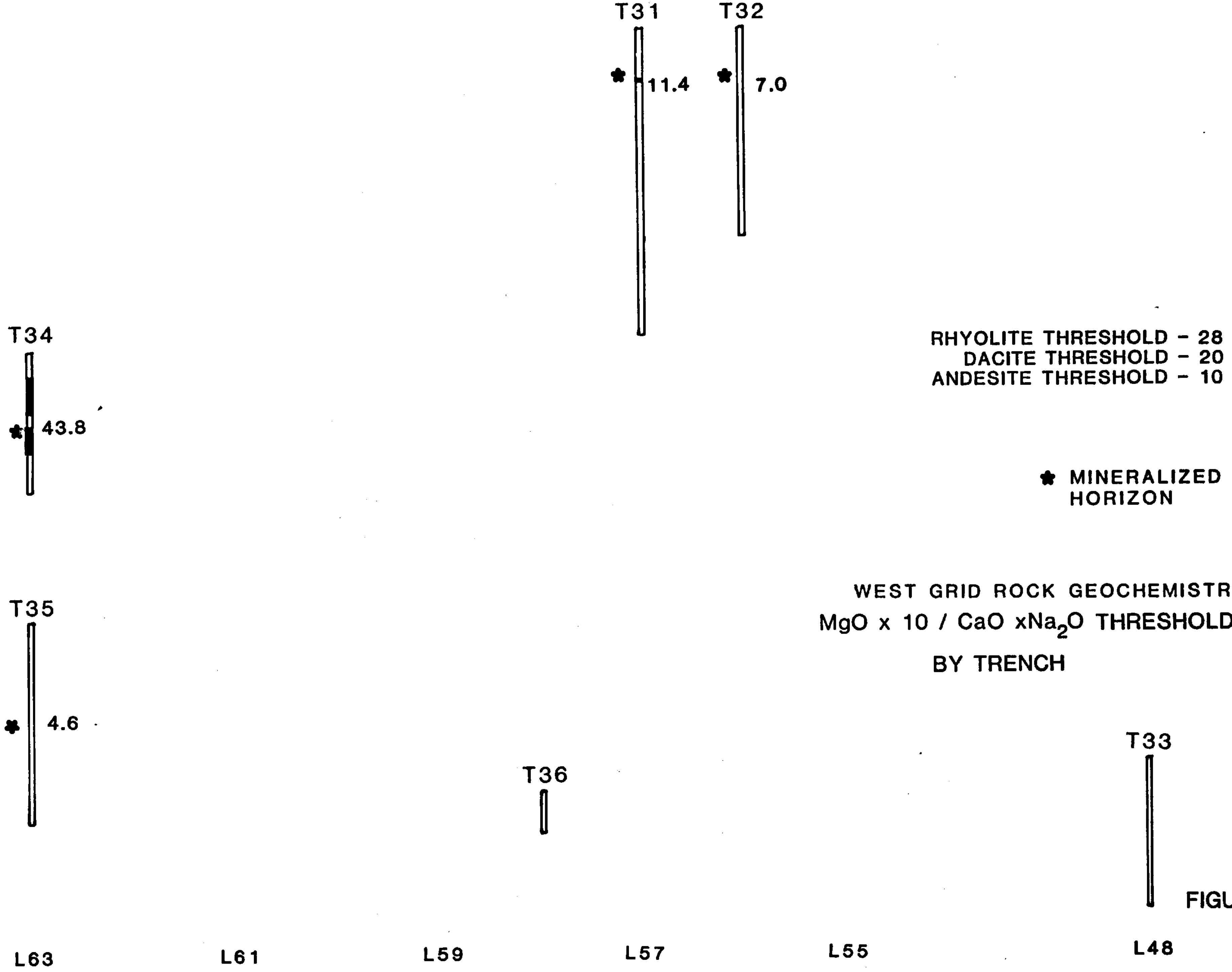
FIGURE 8



WEST GRID ROCK GEOCHEMISTRY

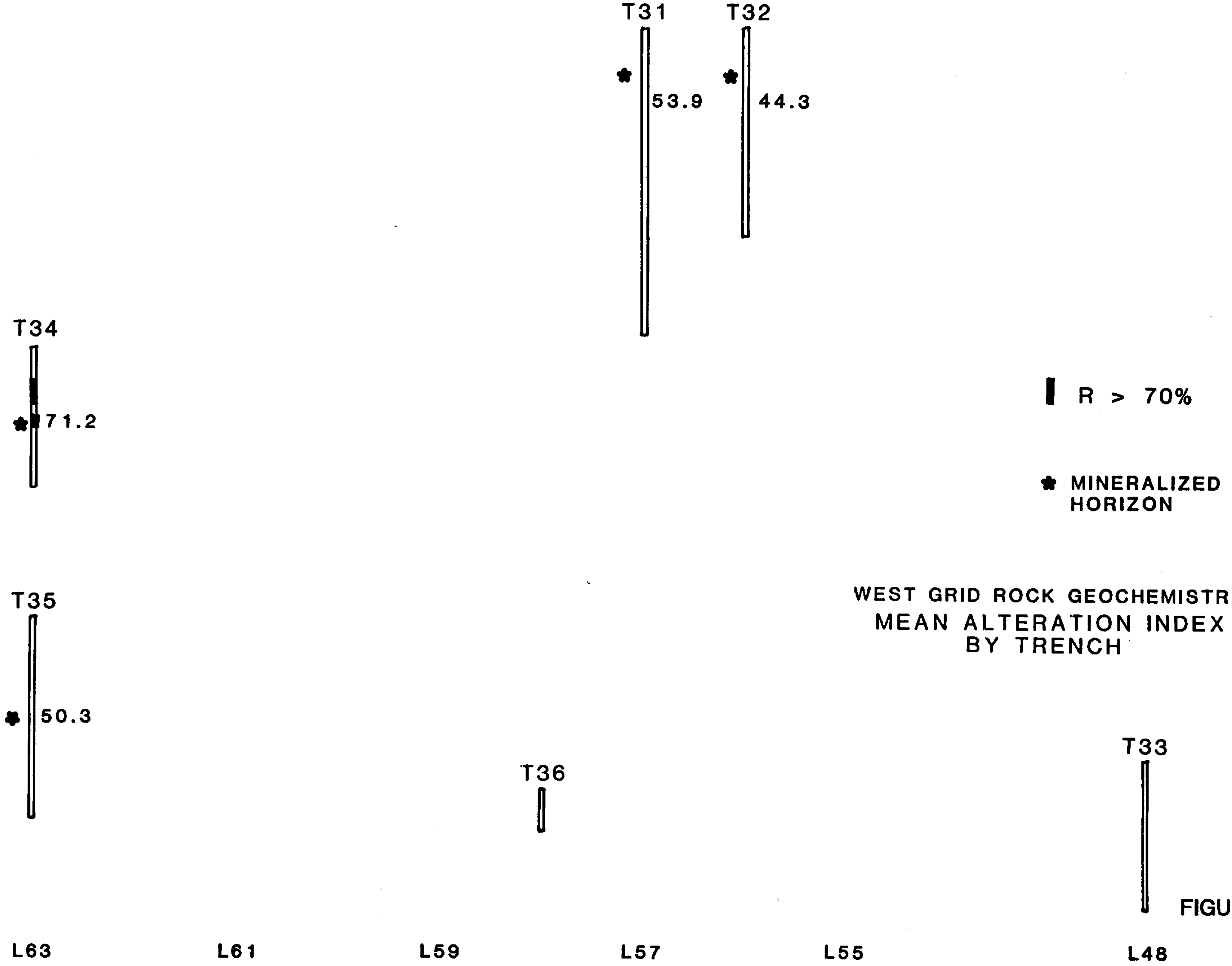
CaO , MEAN CONCENTRATION , BY TRENCH

FIGURE 9



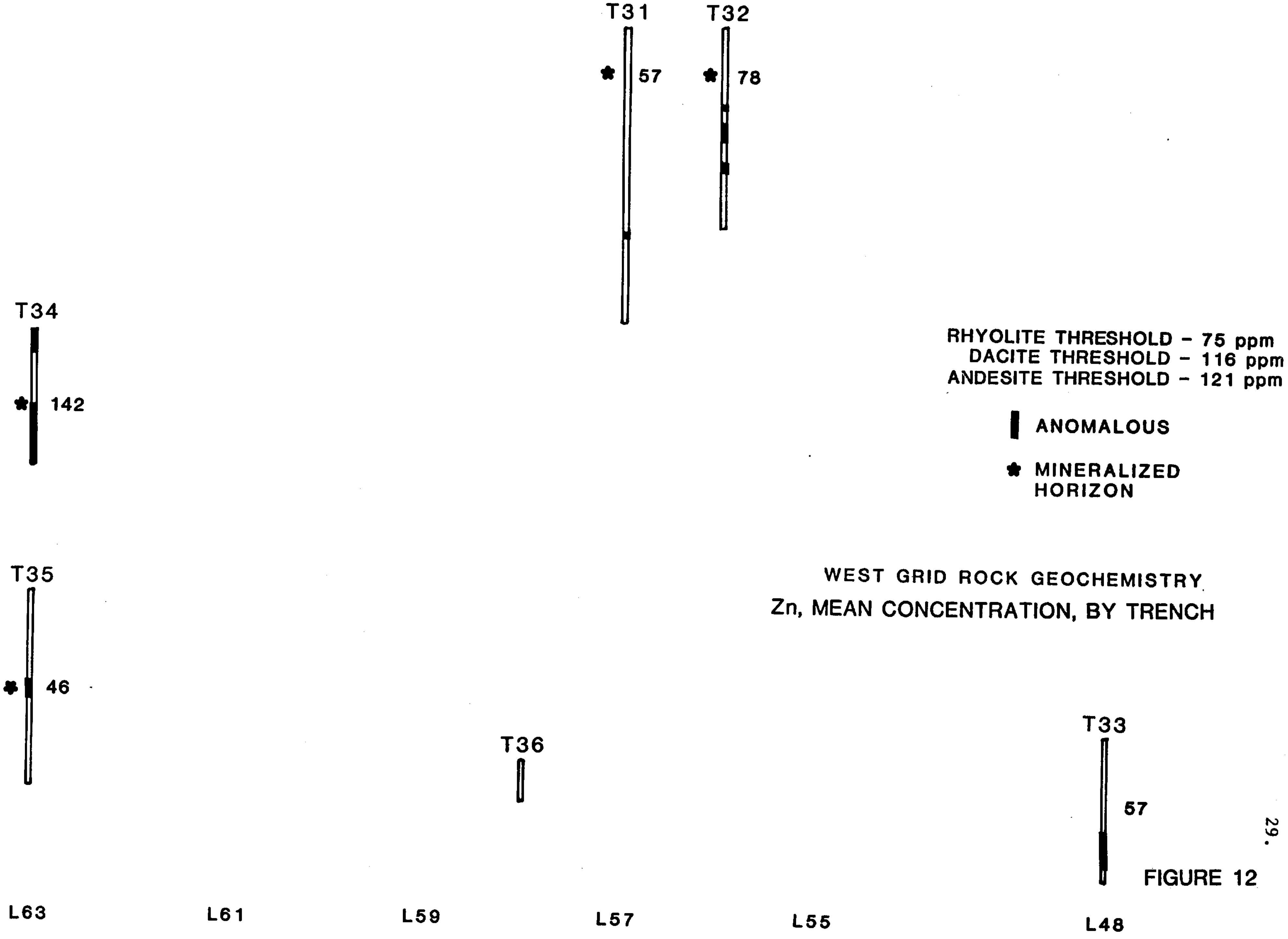
WEST GRID ROCK GEOCHEMISTRY
MgO x 10 / CaO xNa_2O THRESHOLD ,
BY TRENCH

FIGURE 10



WEST GRID ROCK GEOCHEMISTRY
MEAN ALTERATION INDEX
BY TRENCH

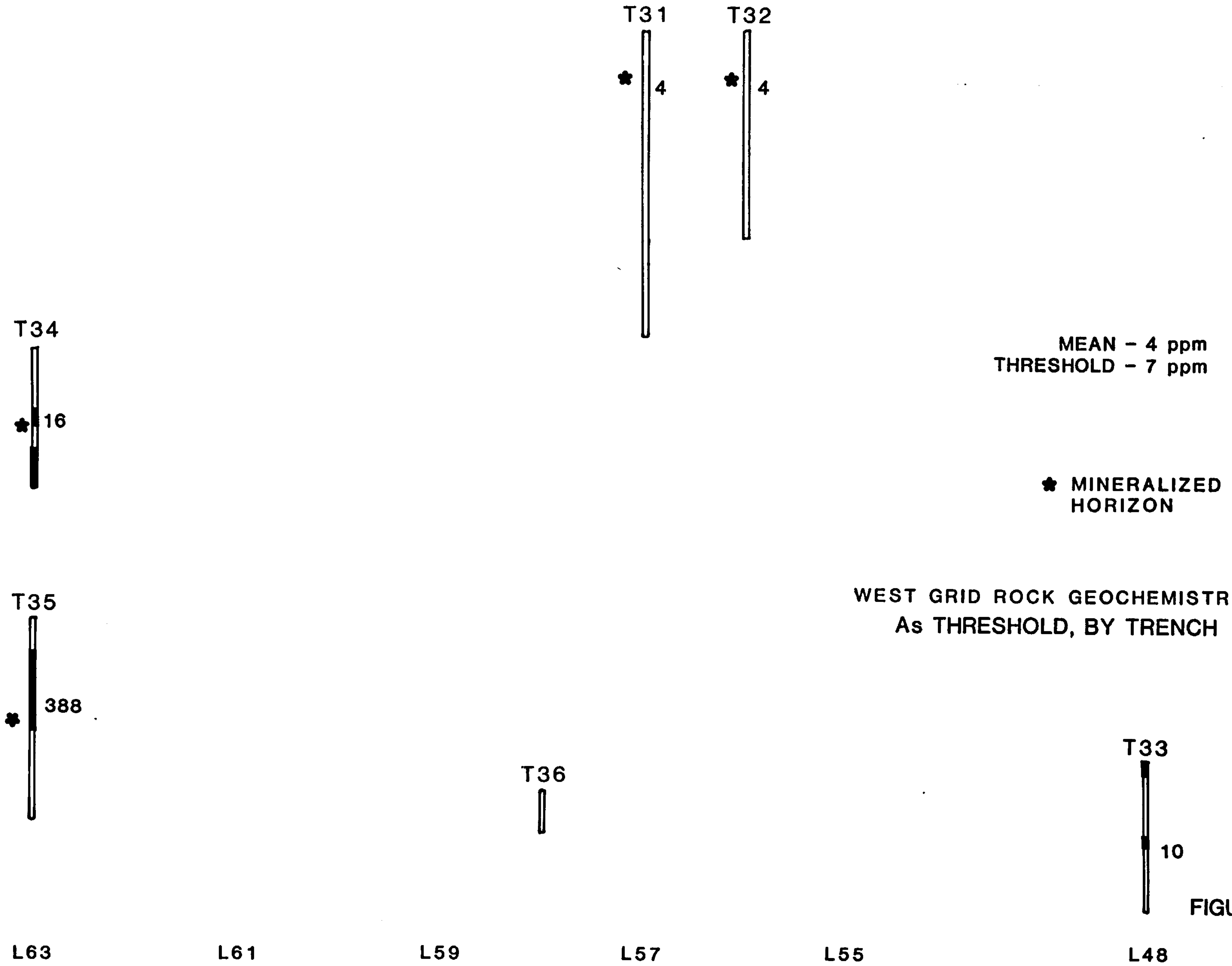
FIGURE 11



WEST GRID ROCK GEOCHEMISTRY

Zn, MEAN CONCENTRATION, BY TRENCH

FIGURE 12



WEST GRID ROCK GEOCHEMISTRY
As THRESHOLD, BY TRENCH

FIGURE 13