GEOCHEMICAL ANALYSIS OF THE 1-ALPINE FEDERAL WELL

by

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ARIZONA GEOLOGICAL SURVEY

1-ALPINE FEDERAL WELL

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Sample Analyses

Samples were analyzed to determine their organic richness, petroleum content, kerogen type, and maturity by TOC and Rock-Eval analyses. Confirmation of maturity on selected samples was completed using vitrinite reflectance and thermal alteration index (TAI) analyses. Free petroleum content was characterized by thermal extraction/gas chromatography fingerprinting. Pyrolysis/gas chromatography was utilized to further characterize kerogen type. Bulk kerogen decomposition kinetic parameters were determined on one source interval to evaluate the temperature and timing thresholds for conversion of organic matter into petroleum.

Discussion of Results

TOC and Rock-Eval Data

The TOC and Rock-Eval analytical results are shown in Table 1. This table shows sample information with respective measured analytical results and calculated interpretive ratios. These data may be summarized as follows:

TOC	organic richness
S1	amount of free petroleum
S2	remaining kerogen potential to generate petroleum
S3	organic carbon dioxide content
Tmax	thermal maturity based on peak yield from Rock-Eval S2 peak
HI	hydrogen index, an important indicator of kerogen type - oil/gas proneness
OI	oxygen index, an indicator of kerogen type
S2/S3	a ratio indicative of kerogen type
PI	production index (S1 / (S1+S2)), indicative of free petroleum content
S1/TOC	normalized petroleum content, indicative of indigenous/migrated petroleum content

Note: When the measured TOC and Rock-Eval data are very low, e.g., TOC < 0.20%, the interpretive ratios are not reliable.

Also shown on these data tables are indications of quality control such as check analyses and pyrogram quality. Approximately 20% of samples are selectively and randomly checked; a confirmed analysis has a "c" is noted in the "check" column. The pyrogram is a graphic representation of the Rock-Eval S2 peak and assists in evaluation of the analytical data. If the S2 value is low (< 0.50 mg hydrocarbons/gram rock) and the S2 pyrogram is flat, the Rock-Eval Tmax value is not usually accurate due to the difficulty of finding a maximum on a flat peak. However, samples having low S2 values but a distinct S2 peak have a Tmax value reported.

Vitrinite Reflectance and Visual Kerogen Data

Four samples were analyzed by microscopy to determine vitrinite reflectance and visual kerogen (maceral) composition to confirm Rock-Eval Tmax maturity assessments (Table II). Analyses of these samples were completed on isolated kerogens which were subsequently mounted in plugs (for vitrinite reflectance measurements and fluorescence) and on slides (for maceral composition assessment). The vitrinite histograms with indigenous and total population statistics and measured data are shown in Appendix I.

Thermal Extract - Pyrolysis / Gas Chromatography Data

Thermal extract / gas chromatography (TE/GC) fingerprints were obtained using whole rock samples. The free petroleum in these rocks was vaporized using a 335°C temperature isotherm for 5 minutes. This is a comparable vaporization temperature used to determine the Rock-Eval S1 peak. Although the Rock-Eval S1 is usually programmed as 300°C temperature isotherm, the true temperature is 30-40°C hotter than this nominal temperature program. The petroleum products vaporized from the rock are trapped directly onto a capillary GC column using liquid nitrogen. Subsequently, the products are chromatographed and detected resulting in the separation of compounds. The GC trace is referred to as afingerprint since it characterizes the petroleum present in the rock. These fingerprints can be likened to histograms or bar graphs with the peaks representing the relative concentration of compounds to one another. Loss of the lightest components (<C8) occurs due to evaporation in sample handling and storage.

Pyrolysis / gas chromatography (PGC) was accomplished by heating the samples at 25°C/minute from 335°C to 550°C. The pyrolysis products were trapped in a capillary GC column and subsequently chromatographed. The typical PGC fingerprint completed by this methodology yields a homologous series of doublets of the same carbon number consisting of alkene-alkane pairs with other hydrocarbons, both saturated and aromatic, eluting between these doublets.

Kinetic Analysis of Potential Oil Source Rocks

One sample having strong oil potential, the 3975 foot shale sample of the Corduroy formation sample of the Permian Supai Group, was analyzed to determine kerogen decomposition kinetic parameters. Source rock kinetic parameters permit description of the timing of decomposition of organic matter which is dependent on kerogen composition as well as temperature and time (Tissot and Espitalie, 1975; Ungerer and Pelet, 1987). Pyrolysis data were acquired at multiple heating rates (1, 5, 10, 15, and 30°C/minute) while measuring both the detector response and true (absolute) temperatures in the sample. A unique technique for precisely measuring temperatures was utilized requiring no linearization or offset corrections to temperatures. The reduced data files were then processed in the rigorous discrete and Gaussian models of the Lawrence Livermore National Laboratory's Kinetics© program.

Only immature samples may be utilized for kinetic analysis.

Interpretation

Analysis of core samples from the 1 Alpine-Federal geothermal well in Apache county, Arizona revealed a number of organic rich intervals. A plot of remaining generation potential (Rock-Eval S2 value) versus TOC shows numerous intervals with greater than 1.00% TOC, the typical minimum organic carbon content for a potential petroleum source rock (Figure 1). The values plotted as an "x" are samples having less than 1.00% TOC whereas the "o" values have TOC contents greater than 1.00%. Values less than 1.00% TOC generally have insignificant petroleum potential and are not usually worth further investigation as potential petroleum source rocks (Baker, 1961).

Intervals at 3294, 3305, and 3340 feet in the Cretaceous have TOC values of 3.11%, 6.59%, and 8.58%, respectively. Likewise, the Permian San Andres limestone reaches 12.77% TOC at 3397 feet and 3.70% at 3410 feet. In the Corduroy formation of the Supai group of Permian age, numerous intervals exceed 1.00% TOC with values over 1.00% ranging from 1.40% to 7.21%. A Fort Apache member of the Supai group measures 4.25% at 4235 feet.

Figure 1 also illustrates the potential for oil and gas of these samples. The Cretaceous intervals are largely gas prone whereas the Permian age samples are more oil prone or have mixed oil/gas potential based on these Rock-Eval S2 and TOC values only. This is also illustrated by a classical modified van Krevelen plot of hydrogen index (Rock-Eval S2 x 100 / TOC) versus oxygen index (Rock-Eval S3 x 100 / TOC) (Figure 2) (Espitalie *et al*, 1977).

Jones (1984) defined the principal products of various kerogen types by HI and OI values as well as by confirmation utilizing elemental and visual kerogen assessment (see Appendix II). Based on HI values only, the Tertiary section is organic lean having no source potential. In the Dakota sandstone of Cretaceous age, there are three organic rich zones. All three zones have HI values which indicate terrestrial derived kerogen which would yield primarily gas upon maturation. In the Permian numerous organic rich zones contain either mixed oil/gas or oil potential based on HI values ranging from 219 to 517. Additional evaluation of kerogen type is discussed in later sections of this report.

A plot hydrogen index versus Rock-Eval Tmax illustrates the remaining petroleum potential with regard to thermal maturity (Figure 3) (Espitalie *et al*, 1984). The majority of the samples are early to mid-oil window in maturity. Two of the organic rich Cretaceous samples have unusually high Tmax values when compared to samples above and below the Cretaceous.

Assessment of samples by vitrinite reflectance and visual kerogen analysis confirms the anomalous maturity profile but this may be due to the nonautchthonous coaly particles (Tables II and Appendix I report and maceral table). However, while the Tmax values may be indicative of more advanced maturity, the lower maturity predicted by vitrinite reflectance assessment (0.63% Ro) is corraborated by the low level conversion of organic matter as indicated by the low production index (<0.05). These Ro and PI values are indicative of 2-10% conversion of kerogen only, i.e., immature to early oil window maturity.

In the lower Fort Apache and Amos Wash Permian Supai Group intervals, very high maturities are indicated by the high Tmax values at 4405 and 4428 feet. While the S2 values are very low in these samples, the S2 peaks have distinct maxima yielding accurate Tmax values. These Tmax values are indicative of gas window maturity suggesting elevated temperature exposures at and below these depths.

Evaluation of Oil Shows

Both dead oil and oil shows were reported at the contact of the Tertiary and Cretaceous, below the San Andres limestone and 196 feet above the top of the Fort Apache unit in the Corduroy formation (4,028 feet). An interpretive ratio from TOC and Rock-Eval S1 data is very useful in predicting shows or reservoir intervals. Depending on sample preservation these data may be used to predict gas or oil reservoirs (Jarvie and Baker, 1984). Since reservoir rocks have high free petroleum content relative to TOC content, e.g., sandstones, when the S1/TOC (x 100) ratio exceeds a value of 100 shows or productive intervals are indicated in the absence of extraneous contamination such as diesel. Potential source rocks in the main phase of oil generation will have much higher S1/TOC ratios than nonsource rocks but will generally have S1/TOC ratios that range from 40 to 80. However, fractured shale reservoirs such as found in the Monterey or Bakken shales, will have S1/TOC ratios greater than 100.

The zones at the Tertiary/Cretaceous boundary have extremely low concentrations of petroleum (< 40 ppm) in intervals between 3156 and 3285 feet. While light hydrocarbons could have evaporated from these samples in storage or sample preparation, the low level of higher hydrocarbons is not indicative of oil shows.

The zone in the Permian Supai group at 4028 feet has a high S1 value (2,430 ppm) and reasonably high S1/TOC (x 100) ratio (69). However, this zone has the characteristics of an organic rich, oil prone petroleum source rock. The TE/GC trace reveals an immature, waxy oil fingerprint (Figure 4.a). Thus, this show is actually caused by *in situ* generation of oil in a potential oil source rock. The pristane/phytane ratio derived from the TE/GC is 0.83 indicative of a reducing depositional environment.

Other zones were also fingerprinted by TE/GC. Two zones in the Cretaceous Dakota formation were fingerprinted. The 3305 feet zone yielded primarily light hydrocarbons characteristic of a gas prone rock (Figure 4.b). The 3340 feet zone has slightly more hydrocarbons above C15 than the 3305 feet zone reflecting its slightly higher HI value (100 vs. 54) (Figure 4.c). However, the principal products are light hydrocarbons. The pristane to phytane ratio exceeds 3 indicative of oxidative depositional environments and terrestrial organic matter input.

The organic rich zone at 3397 feet in the Permian San Andres limestone also yields primarily light hydrocarbons (Figure 4.d) as indicated by the gas prone nature of this sample based on its HI value. The sample at 3410 feet, however, has a more complex fingerprint and contains compounds evolving above C15 including an unresolved envelope from C10 to C30 (Figure 4.e). These are largely nonhydrocarbon petroleum compounds such as resins and asphaltenes which are

not resolved by GC techniques. The oil prone but immature nature of this zone is confirmed by this fingerprint. The pristane/phytane ratio is 2.83.

The zone at 3878 feet in the Permian Corduroy formation of the Supai Group has an HI value of 382 and the TE/GC fingerprint reflects its low maturity, oil potential (Figure 4.f). The TE/GC fingerprint contains an abundance of compounds eluting above C15 with terrestrial input indicated by the C30+ hydrocarbons. The pristane/phytane ratio is 2.39.
The 3975 feet zone of the Corduroy formation has TE/GC fingerprint indicative of lower terrestrial organic matter input than the 3878 feet interval (Figure 4.g). There is an abundance of light hydrocarbons indicative of the tighter, nonporous nature of this sample. Hydrocarbons above C15 are abundant and the pristane to phytane ratio is 1.17.

The Fort Apache member sample at 4235 feet from the Permian Supai Group yields a strong immature oil-like fingerprint from TE/GC (Figure 4.h). There are abundant hydrocarbons present up to C30+ with a significant unresolved component beneath the resolved peaks from C10 to C30. The pristane/phytane ratio is 1.75.

A plot of the relationship of the branched alkanes of biological origen, pristane and phytane, to the straight chain alkanes, C17 and C18, respectively, is indicative of the depositional environment and maturity off these organic rich zones (Figure 5).

Further Evaluation of Kerogen Type from Pyrolysis/Gas Chromatography Fingerprints

Pyrolysis/gas chromatography fingerprints provide a non-petroleum fingerprint of the present day potential of the kerogen to yield oil or gas. Immature gas prone kerogens have PGC fingerprints with low concentrations of normal alkanes especially above C15, a large number of non-alkene/alkane peaks, and high relative amounts of aromatic compounds such as benzene, toluene, and xylenes. On the other hand, immature oil prone kerogens have relatively high amounts of alkene-alkane pairs above C15 with variable amounts of intermediate peaks and low relative amounts of aromatics.

The gas prone kerogens are confirmed by the PGC fingerprints of samples at depths of 3305, 3340, 3397, and 3410 feet (Figure 6.b - 6.e). These fingerprints have relatively low amounts of hydrocarbons above C15 with relatively large amounts of aromatics to alkene-alkane pairs. The 3410 feet sample, despite its relatively high HI value and low maturity, is more gas prone than expected.

On the other hand, the oil prone kerogens are represented by PGC fingerprints of samples at depths of 3878, 3975, 4028, and 4235 feet (Figures 6.a - 6.f-h). There are abundant alkene-alkane pairs extending beyond C15, generally with low amounts of intermediate peaks although the sample at 4235 feet does have a more complex mixture of hydrocarbons. These PGC data confirm the oil prone nature of these zones.

Kinetic Data

The immature 3975 foot sample of the Corduroy formation of the Permian Supai Group was analyzed to determine kerogen decomposition kinetics. These results are shown in Table III. A bar graph of the distribution of activation energies is shown in Figure 7 with the calculated Arrhenius factor (A). The distribution of activation energies is very narrow with over 75% of the kerogen decomposition characterized by a single activation energy. This indicates that the formation of petroleum will occur rapidly over a very narrow range of temperatures and time. This is illustrated by modeling these kinetic data using a constant heating rate geological model by increasing the temperature at 3.3°C per million years. This heating rate may not necessarily be appropriate for this area but permits comparison to other kerogens. In fact changes in the heating rate will cause the temperatures of 10%, 50% and peak generation to shift - if the heating rate is slower, the temperatures will be lower; if the heating rate is faster, the temperatures will be higher.

Using the discrete model kinetic data in a 3.3°C/my constant heating rate model, the generation rate reaches a maximum at 150°C at a computed vitrinite reflectance value (%Ro) of 0.99% (Figure 8).

A plot of the transformation ratio, i.e., the percentage conversion of kerogen to oil or gas, versus temperature using the 3.3°C/my model illustrates the transformation of kerogen to oil (Figure 9). Based on the measured kinetic parameters and this constant heating rate model, 10% generation or the onset of generation, would be reached at 136°C or a computed vitrinite reflectance (%Ro) equivalent of 0.82%. A transformation of 50%, approximately peak generation, would be reached at a temperature of 148°C or 0.96% Ro. The analytical accuracy of these results is typically 5°C. Note the steep slope of the Corduroy formation transformation curve (solid triangles) indicative of the homogenous organic matter in this sample.

How do these results compare to other known petroleum source rocks? Figure 9 compares the transformation ratio of the Corduroy formation sample at 3,975 feet to other kerogens. These results are nearly identical to the Type I (Green River shale) modeled at the identical constant heating rate which decomposes at temperatures slightly higher than the Type IID Woodford shale up to approximately 65% transformation. The Type IIB, IIS, and III kerogens are represented by Kimmeridge shale, a sulfur-rich Monterey formation, and Indiana coal samples, respectively. The computed Rock-Eval Tmax values for the onset of generation (10% transformation ratio) and peak generation would be 441°C and 449°C, respectively, assuming a 35°C correction from true temperatures calculated using these kinetics. This narrow Tmax range is typical of homogenous organic matter yielding primarily paraffinic oil upon maturation.

Conclusions

The 1 Alpine-Federal well is characterized by numerous organic rich but thermally immature intervals. Potential gas, mixed oil/gas, and oil source rocks are present but their potential as commercial oil or gas source rocks is dependent on the maturity and volume of organic rich rocks which would cause generation and expulsion of commercial volumes of oil or gas as well as on

other components of a viable petroleum system including migration pathway, trap, seal, etc. (Magoon and Dow, 1994).

The Cretaceous rocks are organic rich but the richness is largely derived from coaly material that is hydrogen poor. The hydrogen indices and visual kerogen analysis indicate that these kerogens are primarily gas prone.

The Permian age rocks are oil prone or mixed oil/gas prone organic matter based on both HI values and visual kerogen assessment. However, these older rocks are immature based on Rock-Eval Tmax and vitrinite reflectance values. Their remaining potential to generate liquid petroleum products is high. In areas where they may be more mature, they have the capability to generate from 128 to 617 barrels of petroleum per acre-foot based on conversion of their present day potential (Rock-Eval S2 values). Their potential as petroleum source rocks is largely dependent on volumetric considerations and thermal maturity.

In the basal Fort Apache member and the Amos Wash formation of the Permian Supai Group, the high Tmax values are indicative of advanced thermal exposure and maturation.

The oil show reported in the well in the Corduroy formation is related to *in-situ* generation of oil in an organic rich interval. No other shows were detected from geochemical evaluation of these samples.

One organic rich, oil prone sample at 3,975 feet decomposes over a narrow time and temperature range based on calculated kerogen decomposition kinetics. Its decomposition is nearly identical to the Type I Green River shale, an oil prone, lacustrine source rock.

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Date: January 9, 1995

References

Tissot, B. and Espitalie, J., 1975, L'evolution thermique de la matiere organique des sediments: Application d'une simulation methematique, *Revue Institut Francais du Petrole*, 30, pp. 743-777.

Ungerer, P. and R. Pelet, 1987, Extrapolation of the kinetics of oil and gas formation from laboratory experiments to sedimentary basins, Nature, Vol. 327, No. 6117, pp. 52-54.

Espitalie, J., M. Madec, and B. Tissot, 1977, Source rock characterization method for petroleum exploration, 9th Annual Offshore Technology Conference, Houston, Texas, Paper OTC 2935.

Espitalie, J., F. Marquis, and I. Barsony, 1984, Geochemical Logging, *in* Analytical Pyrolysis, K. J. Voorhees, *ed.*, pp.276-304.

Jarvie, D. M. and D. R. Baker, 1984, Application of the Rock-Eval III Oil Show Analyzer to the study of hydrocarbons in an Oklahoma gas well, 187th ACS National Meeting, St. Louis, Missouri.

Jones, R. W., 1984, Comparison of Carbonate and Shale Source Rocks, *in* Petroleum Geochemistry and Source Rock Potential of Carbonate Rocks, AAPG Studies in Geology 18, J. Palacas, *ed.*, pp. 163-180.

Magoon, Leslie B. and W. G. Dow, 1994, The Petroleum System, *in* The Petroleum System - From Source to Trap, L. B. Magoon and W. G. Dow, *eds.*, AAPG Memoir 60, pp.3-24.

Table I.1

ARIZONA GEOLOGICAL SURVEY

WELL NAME: #1 Alpine-Federal
ATTN: Steven Rauzi

SAMPLE NO.	DEPTH (ft)	AGE/ FORMATION	TOC AND ROCK-EVAL DATA					INTERPRETIVE RATIOS					NOTES	
			TOC	S1	S2	S3	TMAX	HI	OI	S2/S3	PI	S1/TOC	Check	Pyrogram
1	504	Tertiary:	0.05	0.04	0.01	0.16	---	20	320	0.06	0.80	80		f
2	553	Datil fm	0.04	0.01	0.00	0.15	---	0	375	0.00	1.00	25		f
3	604		0.03	0.07	0.00	0.13	---	0	433	0.00	1.00	233		f
4	652		0.04	0.02	0.00	0.09	---	0	225	0.00	1.00	50	c	f
5	714		0.02	0.02	0.00	0.12	---	0	600	0.00	1.00	100		f
6	754		0.07	0.03	0.00	0.18	---	0	257	0.00	1.00	43		f
7	804		0.02	0.01	0.00	0.10	---	0	500	0.00	1.00	50		f
8	854		0.04	0.01	0.02	0.11	---	50	275	0.18	0.33	25		f
9	904		0.05	0.01	0.00	0.11	---	0	220	0.00	1.00	20		f
10	954		0.04	0.01	0.01	0.15	---	25	375	0.07	0.50	25		f
11	1002		0.04	0.00	0.00	0.11	---	0	275	0.00	---	0		f
12	1064		0.04	0.01	0.00	0.10	---	0	250	0.00	1.00	25	c	f
13	1114	Tertiary:	0.04	0.01	0.00	0.16	---	0	400	0.00	1.00	25		f
14	1164	Baca fm.	0.06	0.01	0.00	0.19	---	0	317	0.00	1.00	17		f
15	1214		0.05	0.02	0.01	0.21	---	20	420	0.05	0.67	40		f
16	1274		0.04	0.01	0.00	0.15	---	0	375	0.00	1.00	25		f
17	1314		0.03	0.01	0.00	0.13	---	0	433	0.00	1.00	33		f
18	1384		0.05	0.00	0.00	0.11	---	0	220	0.00	---	0		f
19	1434		0.04	0.01	0.00	0.17	---	0	425	0.00	---	25	c	f
20	1481		0.05	0.00	0.00	0.21	---	0	420	0.00	---	0		f
21	1534		0.03	0.00	0.00	0.16	---	0	533	0.00	---	0		f
22	1584		0.07	0.01	0.01	0.13	---	14	186	0.08	0.50	14		f
23	1634		0.06	0.00	0.00	0.20	---	0	333	0.00	---	0		f
24	1694		0.06	0.01	0.00	0.11	---	0	183	0.00	1.00	17		f
25	1750		0.09	0.03	0.02	0.13	---	22	144	0.15	0.60	33	c	f

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Table I.2

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WELL NAME: #1 Alpine-Federal
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SAMPLE	DEPTH	AGE/	TOC AND ROCK-EVAL DATA					INTERPRETIVE RATIOS					NOTES	
No.	(ft)	FORMATION	TOC	S1	S2	S3	TMAX	HI	OI	S2/S3	PI	S1/TOC	Check	Pyrogram
26	1800		0.05	0.00	0.00	0.12	---	0	240	0.00	---	0		f
27	1848		0.06	0.01	0.01	0.13	---	17	217	0.08	0.50	17	c	f
28	1902		0.04	0.00	0.00	0.09	---	0	225	0.00	---	0		f
29	1953		0.03	0.00	0.00	0.14	---	0	467	0.00	---	0		f
30	2002		0.04	0.01	0.03	0.20	---	75	500	0.15	0.25	25		f
31	2052		0.04	0.01	0.00	0.16	---	0	400	0.00	1.00	25		f
32	2104		0.03	0.01	0.01	0.26	---	33	867	0.04	0.50	33		f
33	2164		0.04	0.00	0.01	0.12	---	25	300	0.08	0.00	0		f
34	2204		0.04	0.01	0.00	0.15	---	0	375	0.00	1.00	25	c	f
35	2254		0.03	0.01	0.00	0.17	---	0	567	0.00	1.00	33		f
36	2304		0.06	0.01	0.00	0.16	---	0	267	0.00	1.00	17		f
37	2364		0.07	0.01	0.00	0.15	---	0	214	0.00	1.00	14		f
38	2404		0.05	0.00	0.00	0.07	---	0	140	0.00	---	0	c	f
39	2464		0.03	0.00	0.00	0.16	---	0	533	0.00	---	0		f
40	2504		0.13	0.01	0.02	0.13	---	15	100	0.15	0.33	8		f
41	2560		0.06	0.01	0.01	0.06	---	17	100	0.17	0.50	17	c	f
42	2604		0.08	0.02	0.02	0.16	---	25	200	0.13	0.50	25		f
43	2663		0.14	0.04	0.02	0.12	---	14	86	0.17	0.67	29		f
44	2704		0.06	0.01	0.05	0.09	---	83	150	0.56	0.17	17		f
45	2754		0.06	0.00	0.00	0.07	---	0	117	0.00	---	0	c	f
46	2802		0.07	0.00	0.03	0.10	---	43	143	0.30	0.00	0		f
47	2862		0.12	0.01	0.05	0.14	---	42	117	0.36	0.17	8	c	f
48	2902		0.03	0.02	0.02	0.08	---	67	267	0.25	0.50	67		f
49	2966		0.09	0.01	0.04	0.09	---	44	100	0.44	0.20	11		f
50	3106		0.12	0.02	0.02	0.12	---	17	100	0.17	0.50	17		f

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Table I.3

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WELL NAME: #1 Alpine-Federal
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SAMPLE No.	DEPTH (ft)	AGE/ FORMATION	TOC AND ROCK-EVAL DATA					INTERPRETIVE RATIOS					NOTES	
			TOC	S1	S2	S3	TMAX	HI	OI	S2/S3	PI	S1/TOC	Check	Pyrogram
51	3156	Tertiary:	0.15	0.02	0.03	0.09	---	20	60	0.33	0.40	13		f
52	3206	(red beds)	0.10	0.02	0.10	0.09	---	100	90	1.11	0.17	20		f
53	3255		0.05	0.03	0.09	0.16	---	180	320	0.56	0.25	60		f
54	3265	Cretaceous:	0.08	0.01	0.08	0.07	429	100	88	1.14	0.11	13		n
55	3275	Dakota SS	0.80	0.04	0.56	0.11	432	70	14	5.09	0.07	5		n
56	3285		0.26	0.03	0.14	0.09	429	54	35	1.56	0.18	12		n
57	3294		3.11	0.06	2.67	0.17	436	86	5	15.71	0.02	2	c	n
58	3305		6.59	0.14	3.59	0.36	449	54	5	9.97	0.04	2	c	n
59	3315		0.90	0.03	0.96	0.16	433	107	18	6.00	0.03	3		n
60	3330		0.54	0.02	0.44	0.09	432	81	17	4.89	0.04	4		n
61	3340		8.58	0.43	8.60	0.60	444	100	7	14.33	0.05	5	c	n
62	3350		0.84	0.01	0.32	0.14	439	38	17	2.29	0.03	1		n
63	3360		0.52	0.01	0.24	0.24	434	46	46	1.00	0.04	2		n
64	3370	Permian:	0.15	0.03	0.04	0.25	---	27	167	0.16	0.43	20	c	f
65	3380	San Andres LS	0.26	0.03	0.45	0.34	427	173	131	1.32	0.06	12		n
66	3390		0.53	0.07	1.31	0.45	425	247	85	2.91	0.05	13		n
67	3397		12.77	1.04	27.95	0.69	420	219	5	40.51	0.04	8	c	n
68	3400		0.05	0.02	0.10	0.28	433	200	560	0.36	0.17	40		n
69	3410		3.70	0.55	15.38	0.70	420	416	19	21.97	0.03	15		n
70	3420		0.78	0.20	2.87	0.57	419	368	73	5.04	0.07	26		n
71	3430		0.20	0.03	0.33	0.42	431	165	210	0.79	0.08	15		n
72	3435		0.31	0.02	0.14	0.27	425	45	87	0.52	0.12	6		n
73	3465	Permian:	0.06	0.05	0.04	0.22	---	67	367	0.18	0.56	83		f
74	3495	Glorieta SS	0.07	0.02	0.03	0.25	---	43	357	0.12	0.40	29	c	f
75	3525		0.04	0.04	0.01	0.26	---	25	650	0.04	0.80	100	c	f

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Table I.4

ARIZONA GEOLOGICAL SURVEY

WELL NAME: #1 Alpine-Federal
ATTN: Steven Rauzi

SAMPLE NO.	DEPTH (ft)	AGE/ FORMATION	TOC AND ROCK-EVAL DATA					INTERPRETIVE RATIOS					NOTES	
			TOC	S1	S2	S3	TMAX	HI	OI	S2/S3	PI	S1/TOC	Check	Pyrogram
76	3555		0.04	0.07	0.01	0.25	---	25	625	0.04	0.88	175		f
77	3585		0.07	0.08	0.02	0.24	---	29	343	0.08	0.80	114		f
78	3615		0.12	0.04	0.04	0.28	---	33	233	0.14	0.50	33		f
79	3645	Permian:	0.16	0.01	0.02	0.42	---	13	263	0.05	0.33	6		f
80	3690	Supai Group	0.14	0.00	0.00	0.33	---	0	236	0.00	---	0		f
		Corduroy fm												
81	3755		0.08	0.05	0.04	0.30	---	50	375	0.13	0.56	63	c	f
82	3785		0.06	0.01	0.01	0.20	---	17	333	0.05	0.50	17		f
83	3795		0.07	0.01	0.01	0.17	---	14	243	0.06	0.50	14		f
84	3805		0.03	0.01	0.02	0.14	---	67	467	0.14	0.33	33		f
85	3815		0.05	0.02	0.02	0.21	---	40	420	0.10	0.50	40	c	f
86	3825		0.02	0.02	0.00	0.18	---	0	900	0.00	1.00	100		f
87	3835		0.02	0.00	0.06	0.00	---	300	0	---	0.00	0		f
88	3845		0.16	0.00	0.03	0.11	---	19	69	0.27	0.00	0		f
89	3865		0.03	0.01	0.01	0.05	---	33	167	0.20	0.50	33		f
90	3878		3.22	0.96	12.29	0.63	436	382	20	19.51	0.07	30	c	n
91	3885		0.15	0.01	0.06	0.13	435	40	87	0.46	0.14	7		n
92	3905		0.15	0.04	0.02	0.23	---	13	153	0.09	0.67	27	c	f
93	3915		1.03	0.45	3.69	0.27	431	358	26	13.67	0.11	44		n
94	3925		0.19	0.03	0.09	0.19	431	47	100	0.47	0.25	16		n
95	3945		0.02	0.03	0.01	0.15	---	50	750	0.07	0.75	150		f
96	3965		0.09	0.07	0.22	0.11	438	244	122	2.00	0.24	78		n
97	3975		7.21	2.68	25.50	0.66	436	354	9	38.64	0.10	37	c	n
98	3975		1.55	0.56	5.81	0.64	434	375	41	9.08	0.09	36		n
99	3985		0.01	0.01	0.02	0.33	---	200	3300	0.06	0.33	100	c	f
100	4005		0.02	0.01	0.01	0.21	---	50	1050	0.05	0.50	50	c	f

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Table I.5

ARIZONA GEOLOGICAL SURVEY

WELL NAME: #1 Alpine-Federal
ATTN: Steven Rauzi

SAMPLE NO.	DEPTH (ft)	AGE/ FORMATION	TOC AND ROCK-EVAL DATA					INTERPRETIVE RATIOS					NOTES	
			TOC	S1	S2	S3	TMAX	HI	OI	S2/S3	PI	S1/TOC	Check	Pyrogram
101	4015		0.20	0.02	0.01	0.14	---	5	70	0.07	0.67	10		f
102	4025		0.14	0.12	0.55	0.12	435	393	86	4.58	0.18	86		n
103	4028		3.54	2.43	18.30	0.50	435	517	14	36.60	0.12	69	c	n
104	4045		0.10	0.02	0.02	0.20	---	20	200	0.10	0.50	20		f
105	4060		0.18	0.11	0.59	0.20	434	328	111	2.95	0.16	61		n
106	4065		1.40	0.66	4.49	0.45	437	321	32	9.98	0.13	47		n
107	4085		0.02	0.03	0.02	0.19	---	100	950	0.11	0.60	150	c	f
108	4089		0.15	0.02	0.12	0.19	439	80	127	0.63	0.14	13		n
109	4105		0.02	0.01	0.01	0.20	---	50	1000	0.05	0.50	50		f
110	4115		0.04	0.01	0.01	0.08	---	25	200	0.13	0.50	25		f
111	4125		1.86	0.31	5.70	0.30	431	306	16	19.00	0.05	17	c	n
112	4130		1.65	0.23	4.48	0.34	433	272	21	13.18	0.05	14		n
113	4145		2.26	0.28	6.02	0.27	435	266	12	22.30	0.04	12	c	n
114	4165		0.08	0.03	0.05	0.18	---	63	225	0.28	0.38	38		f
115	4185		0.11	0.02	0.17	0.17	---	155	155	1.00	0.11	18		f
116	4205		0.11	0.01	0.01	0.13	---	9	118	0.08	0.50	9		f
117	4225	Permian:	0.22	0.03	0.06	0.24	---	27	109	0.25	0.33	14	c	f
118	4230	Supai group	0.12	0.06	0.15	0.22	439	125	183	0.68	0.29	50		n
119	4235	Fort Apache mbr	4.25	2.26	16.66	0.56	431	392	13	29.75	0.12	53	c	n
120	4245		0.07	0.03	0.05	0.41	435	71	586	0.12	0.38	43		n
121	4255		0.24	0.02	0.07	0.26	---	29	108	0.27	0.22	8		f
122	4260		0.16	0.02	0.06	0.28	---	38	175	0.21	0.25	13		f
123	4265		0.10	0.01	0.08	0.21	---	80	210	0.38	0.11	10		f
124	4295		0.14	0.00	0.01	0.20	---	7	143	0.05	0.00	0		f
125	4325		0.87	0.10	0.11	0.25	362	13	29	0.44	0.48	11		ltS2

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Table I.6

ARIZONA GEOLOGICAL SURVEY

WELL NAME: #1 Alpine-Federal
ATTN: Steven Rauzi

SAMPLE NO.	DEPTH (ft)	AGE/ FORMATION	TOC AND ROCK-EVAL DATA					INTERPRETIVE RATIOS					NOTES	
			TOC	S1	S2	S3	TMAX	HI	OI	S2/S3	PI	S1/TOC	Check	Pyrogram
126	4355		0.12	0.01	0.03	0.27	---	25	225	0.11	0.25	8	c	f
127	4365		0.13	0.08	0.03	0.17	---	23	131	0.18	0.73	62		f
128	4375		0.22	0.11	0.03	0.17	---	14	77	0.18	0.79	50		f
129	4385		0.51	0.14	0.06	0.17	---	12	33	0.35	0.70	27	c	f
130	4395		0.27	0.07	0.02	0.20	---	7	74	0.10	0.78	26		f
131	4397		0.25	0.08	0.04	0.16	---	16	64	0.25	0.67	32		f
132	4402		0.14	0.07	0.05	0.20	---	36	143	0.25	0.58	50		f
133	4405		0.18	0.02	0.12	0.12	520	67	67	1.00	0.14	11		n
134	4409		0.23	0.03	0.06	0.16	---	26	70	0.38	0.33	13		f
135	4413		0.12	0.02	0.05	0.09	---	42	75	0.56	0.29	17		f
136	4415	Permian:	0.03	0.05	0.07	0.20	---	233	667	0.35	0.42	167		f
137	4425	Supai group	0.04	0.01	0.04	0.07	---	100	175	0.57	0.20	25		f
138	4428	Amos Wash fm	0.24	0.02	0.44	0.20	484	183	83	2.20	0.04	8	c	n
139	4435	(Big A Butte mbr)	0.13	0.11	0.10	0.15	351	77	115	0.67	0.52	85		ltS2
140	4445		0.13	0.01	0.07	0.14	---	54	108	0.50	0.12	8		f
141	4455		0.16	0.01	0.02	0.20	---	13	125	0.10	0.33	6		f
142	4485		0.17	0.00	0.18	0.19	---	106	112	0.95	0.00	0		f
143	4505	Total Depth	0.11	0.04	0.06	0.53	---	55	482	0.11	0.40	36		f

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* Tmax data not reliable due to low S2 values
TOC = weight percent organic carbon
S1, S2 = mg hydrocarbons/g rock
S3 = mg carbon dioxide/g rock
Tmax = Degree C

HI = S2*100/TOC
OI = S3*100/TOC
PI = S1/(S1+S2)
S1/TOC = S1*100/TOC

NOTES:
Check
c = sample analysis confirmed
Pyrogram
n = normal
f = flat (no peak)
ltS2 = low temperature S2 peak

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TABLE II

ARIZONA GEOLOGICAL SURVEY

WELL NAME: #1 Alpine Federal
ATTN: Steven Rauzi

SAMPLE TYPE	DEPTH (ft)	TOC	TMAX	S2	HI	Kerogen Type	Mean Ro	Remarks
core	3305	6.59	449	3.59	54	C(100)	0.65	Picked Coal; Good but immature gas source
core	3340.0	8.58	444	8.60	100	C(100)	0.62	Picked Coal; Good but immature gas source
core	3878.0	3.22	436	12.29	382	Am(95) C(5)	0.42	Yellow-Orange flour. Exc Excellent but immature oil source
core	4235.0	4.25	431	16.66	392	Am(97) C(3)	0.40	Excellent potential oil source; immature

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Am= Amorphous C = Coaly

Table III

ARIZONA GEOLOGICAL SURVEY
1 ALPINE-FEDERAL

HGS DERIVED KINETIC PARAMETERS
Five heating rates: 1, 5, 10, 15, and 30 C/min (in duplicate)

Sample ID.	Corduroy Fm. Permian Supai Group 3,975 feet		
HGS Sample ID.	94A-64-97		
Kinetics Output File Name:	SUPAI.OUT		
Arrhenius factor (/sec)	4.0475E+13		
Discrete Model Results	Percent of Reaction		
Activation Energy (kcal/mole)			
40			
41			
42			
43			
44			
45			
46	0.29		
47	0.51		
48			
49			
50			
51			
52			
53	79.51		
54	0.81		
55	12.14		
56			
57	6.74		
58			
59			
60			
61			
62			
63			
64			
65			
66			
67			
68			
69			
70			
Approximate Error - S (%Ea)	1.74		
GAUSSIAN RESULTS:			
n = 1 A (/sec)	5.1491E+13		
Ea (cal/mole)	53623		
S (%Ea)	1.57		
Best Reaction Order (n)	1.20		
3 Parameter Narrow Profile Results:			
A (/sec)	na		
Ea (cal/mole)	na		
(1-x) exponent (m)	na		

AGS #1 ALPINE-FEDERAL

ORGANIC FACIES PLOT

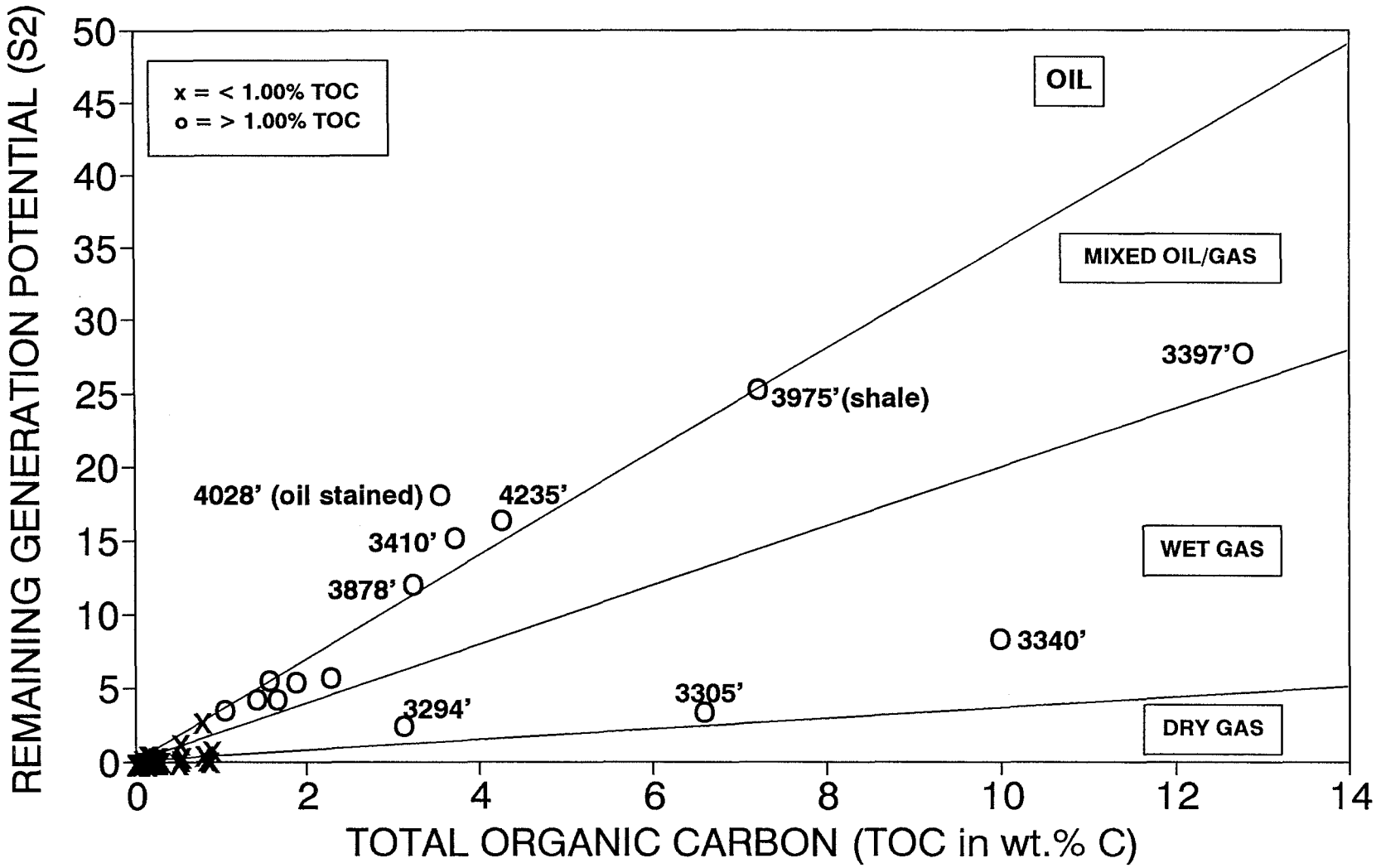


Figure 1
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

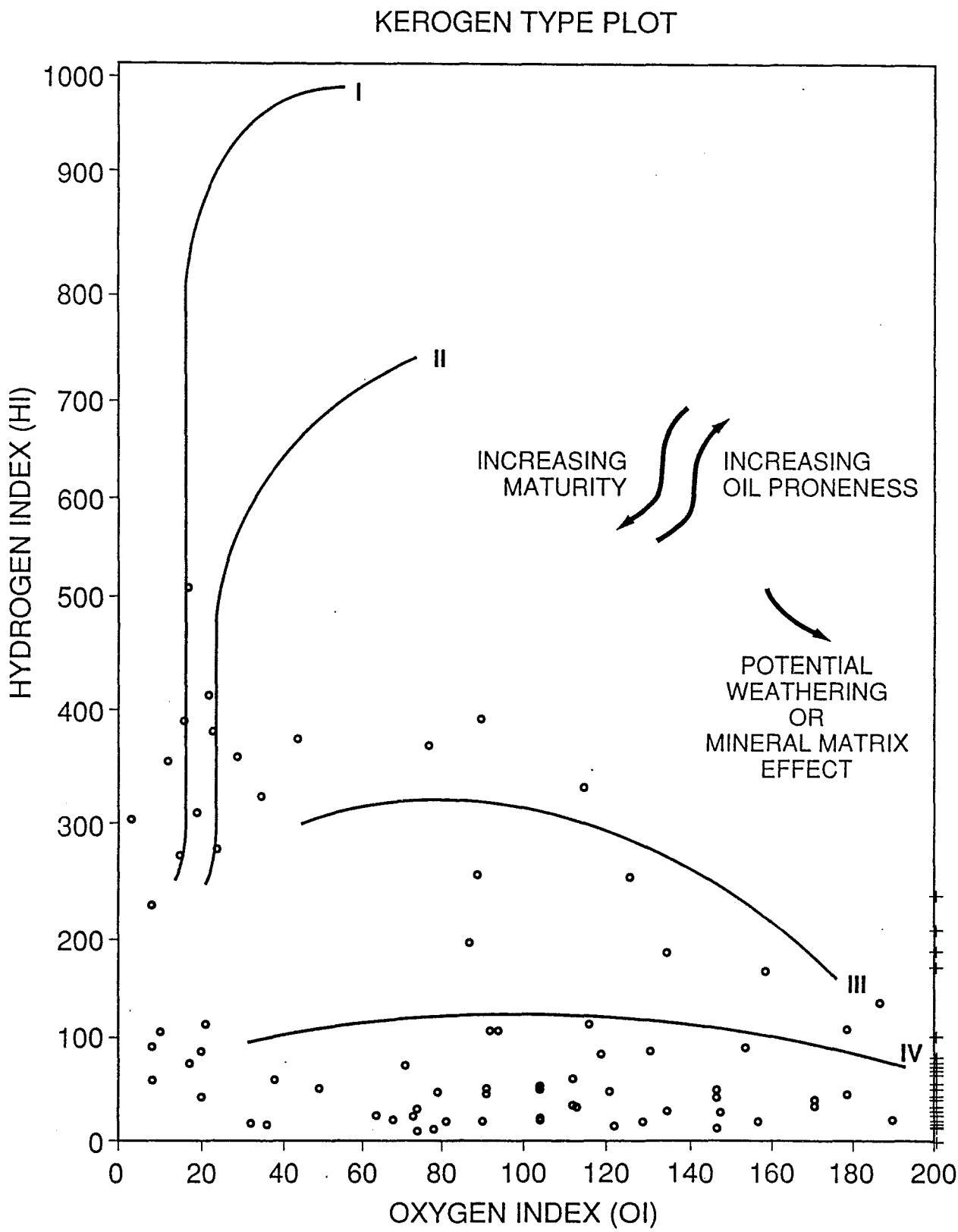
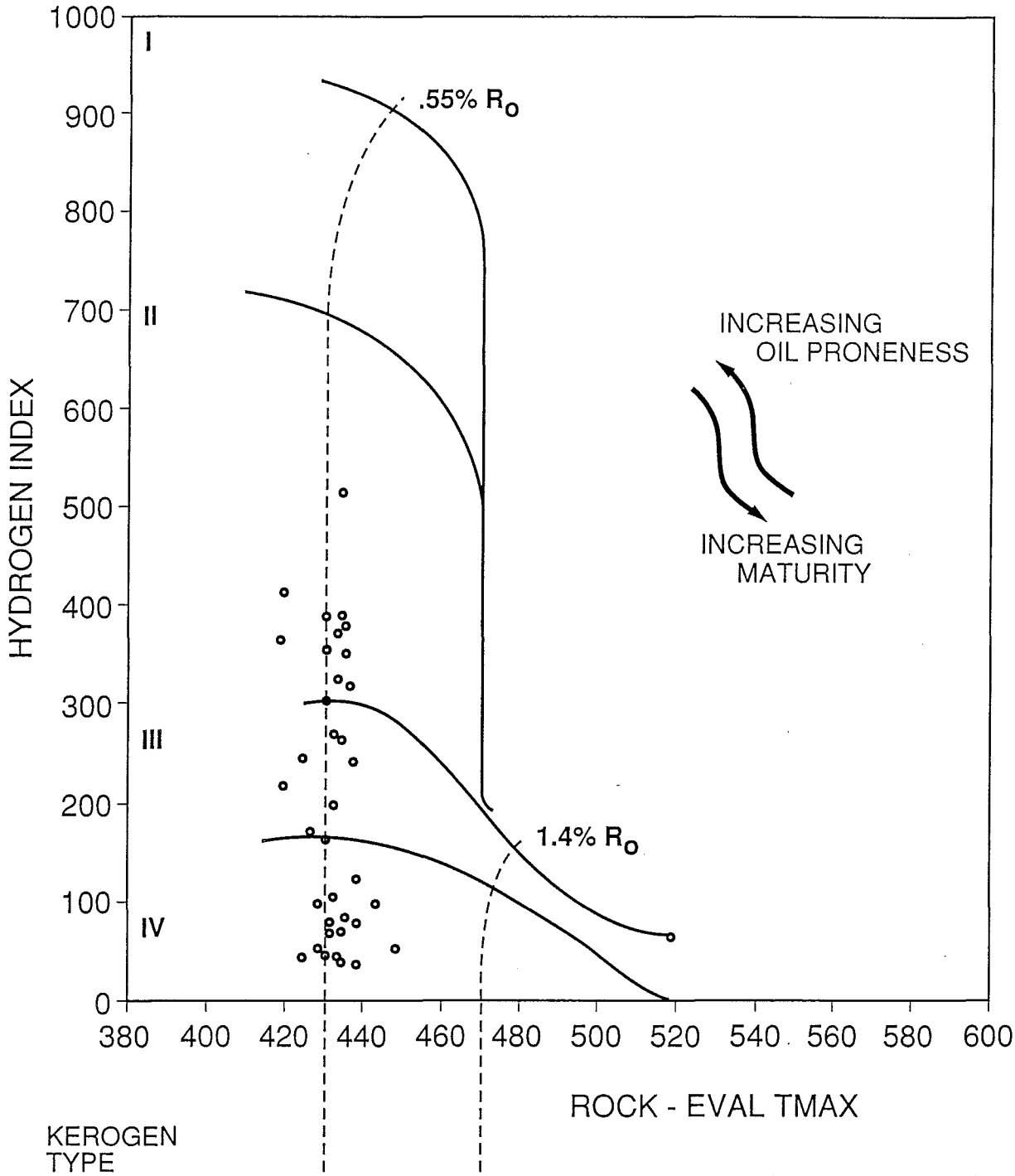

KEROGEN TYPE PLOT
HYDROGEN INDEX (HI)
OXYGEN INDEX (OI)
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
180
200
I
II
III
IV
INCREASING MATURITY
INCREASING OIL PRONENESS
POTENTIAL WEATHERING OR MINERAL MATRIX EFFECT

Figure 2

ARIZONA GEOLOGICAL SURVEY
NEW MEXICO STATE UNIVERSITY
#1 ALPINE-FEDERAL

KEROGEN TYPE AND MATURITY PLOT



KEROGEN TYPE			
I	IMMATURE	OIL	GAS
II	IMMATURE	OIL	GAS
III	IMMATURE	OIL	GAS

Figure 3

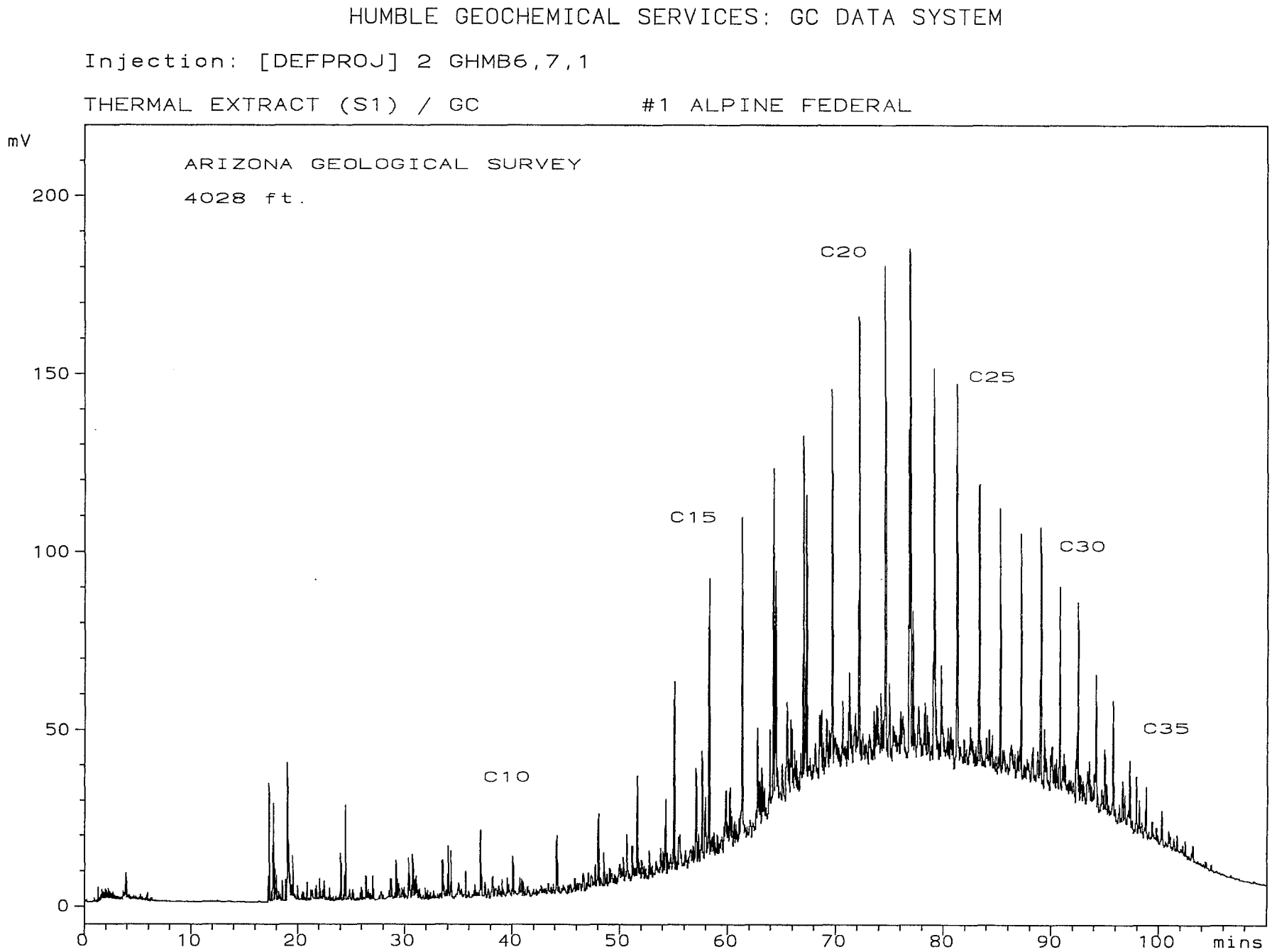


Figure 4.a
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

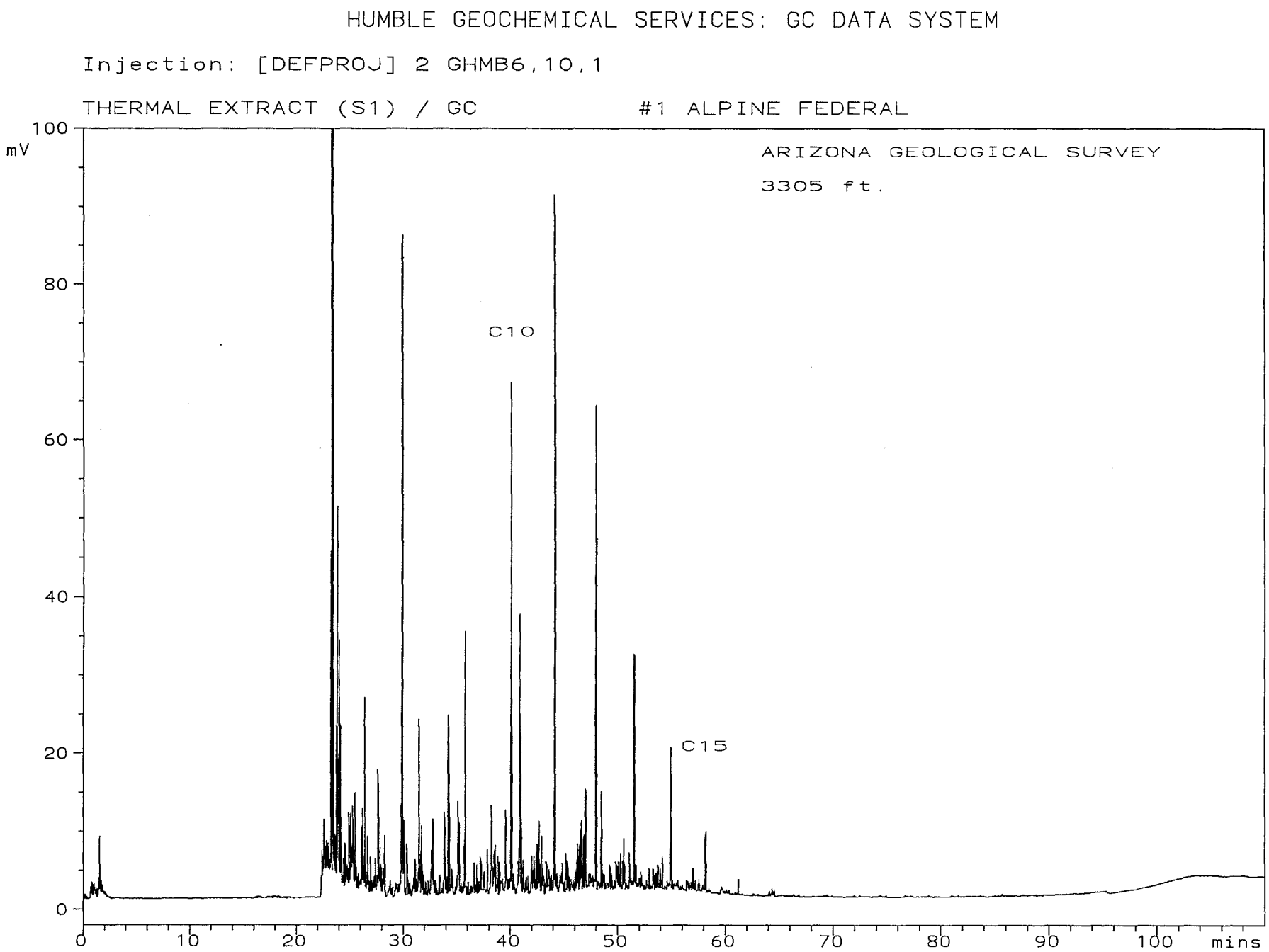


Figure 4.b
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

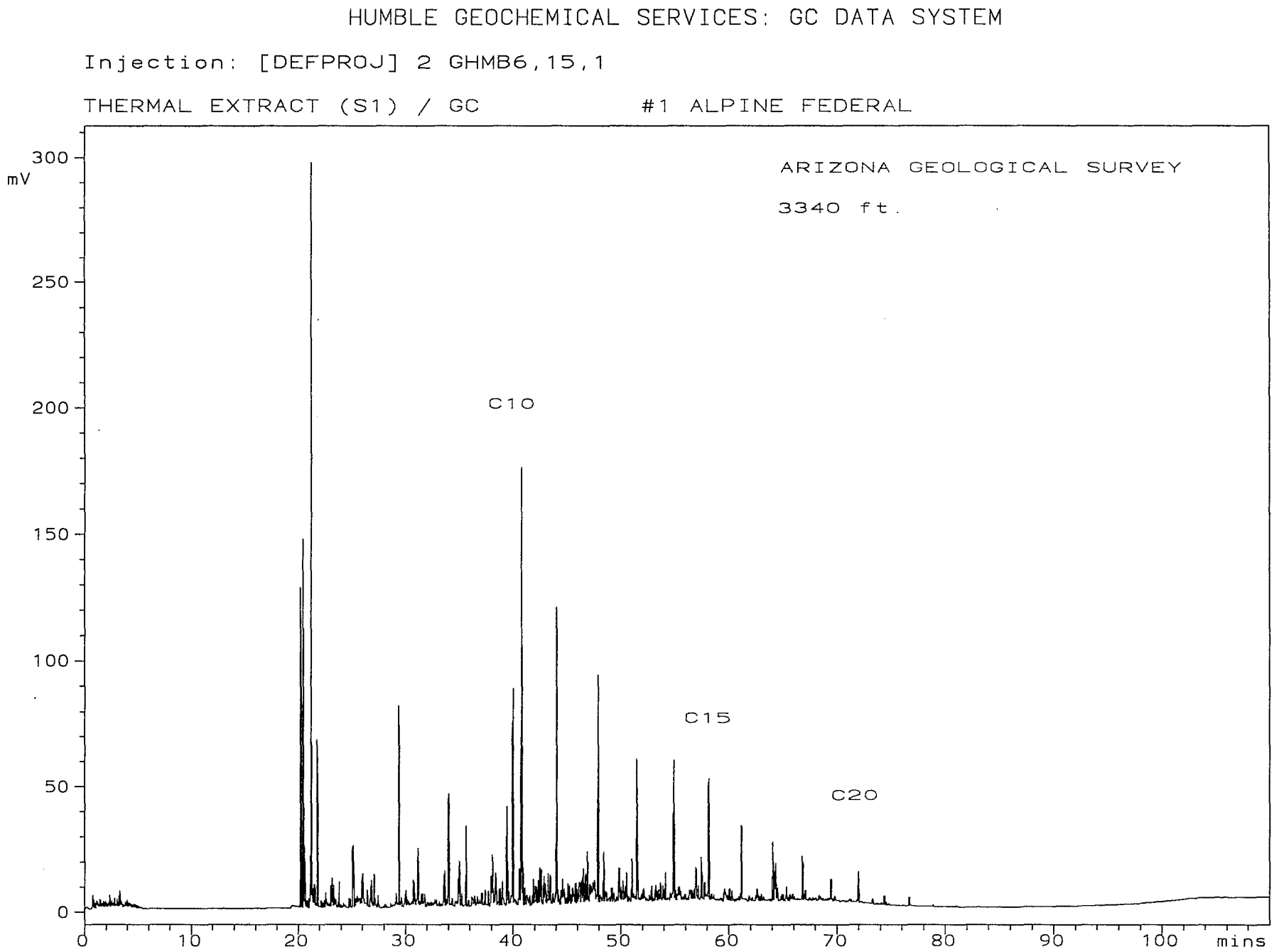


Figure 4.c
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

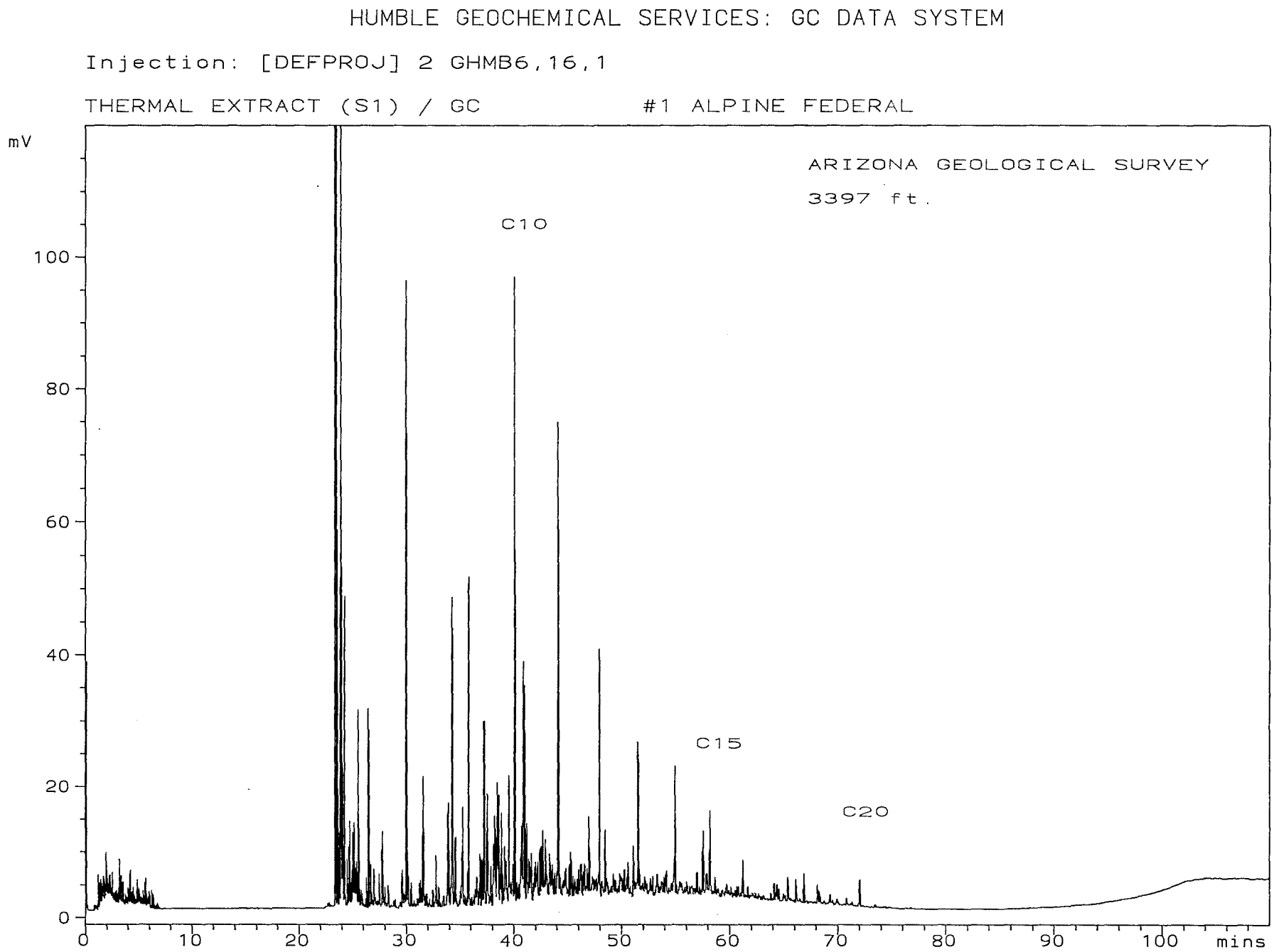


Figure 4.d
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

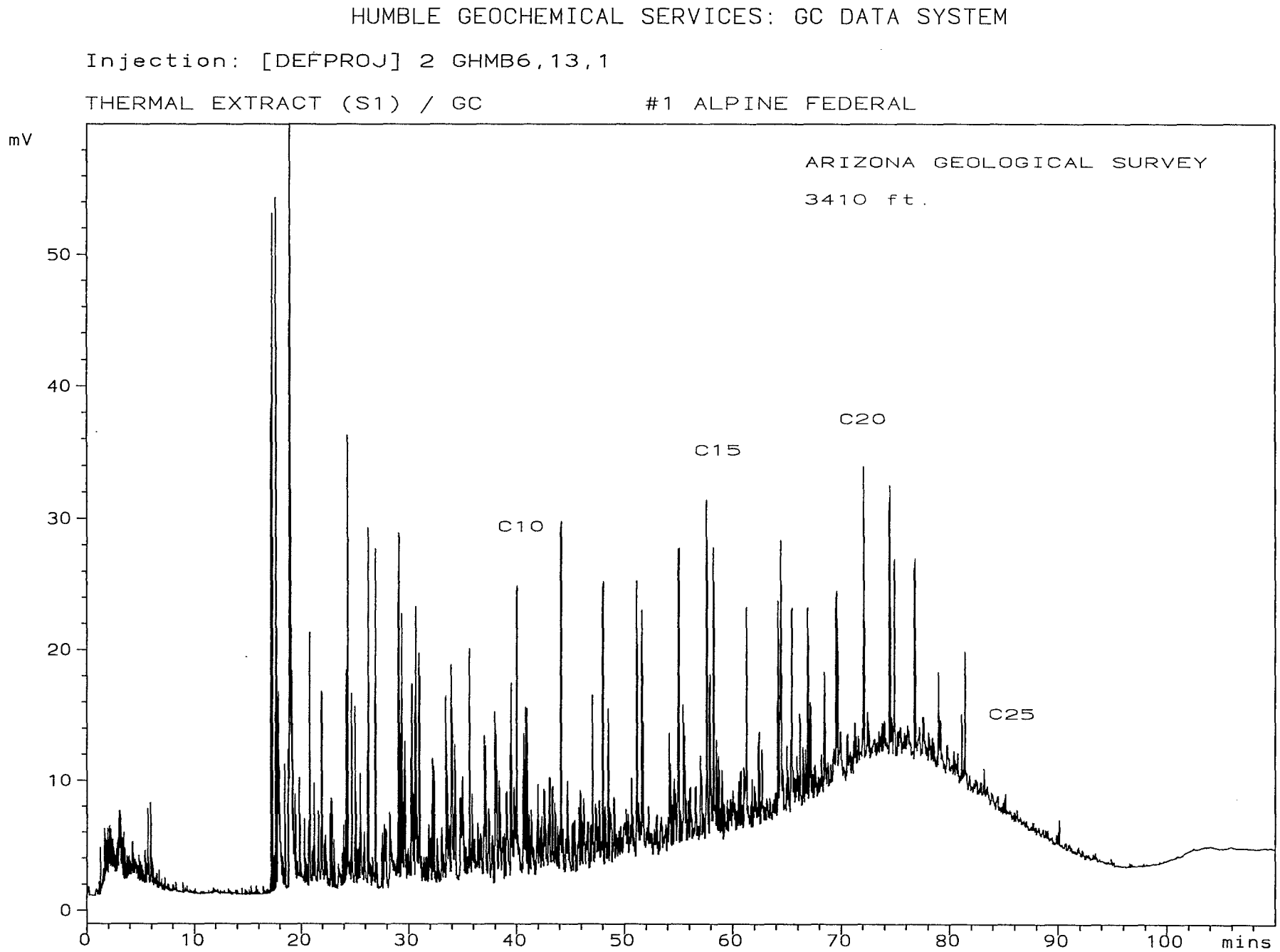


Figure 4.e
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

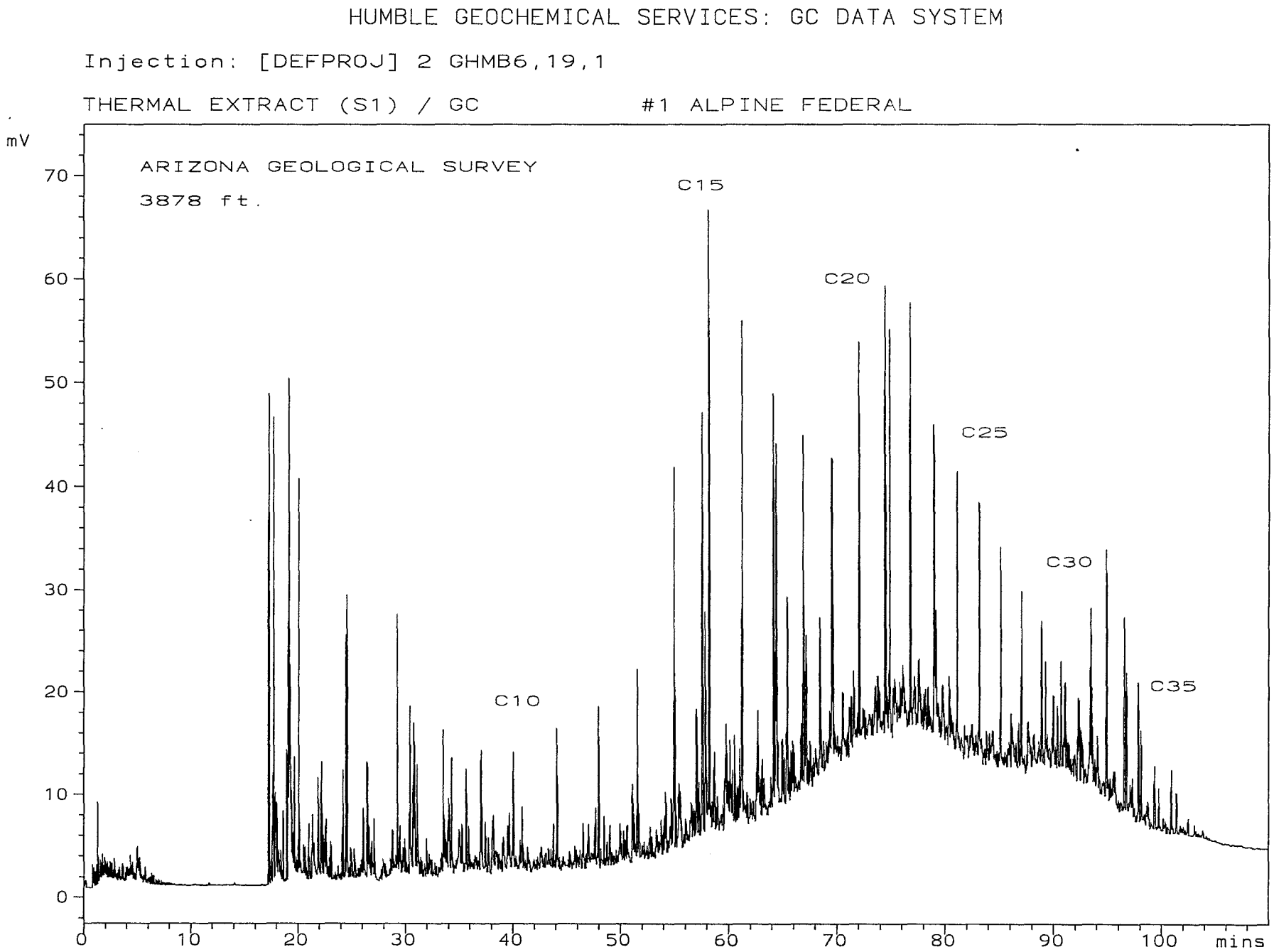


Figure 4.f
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

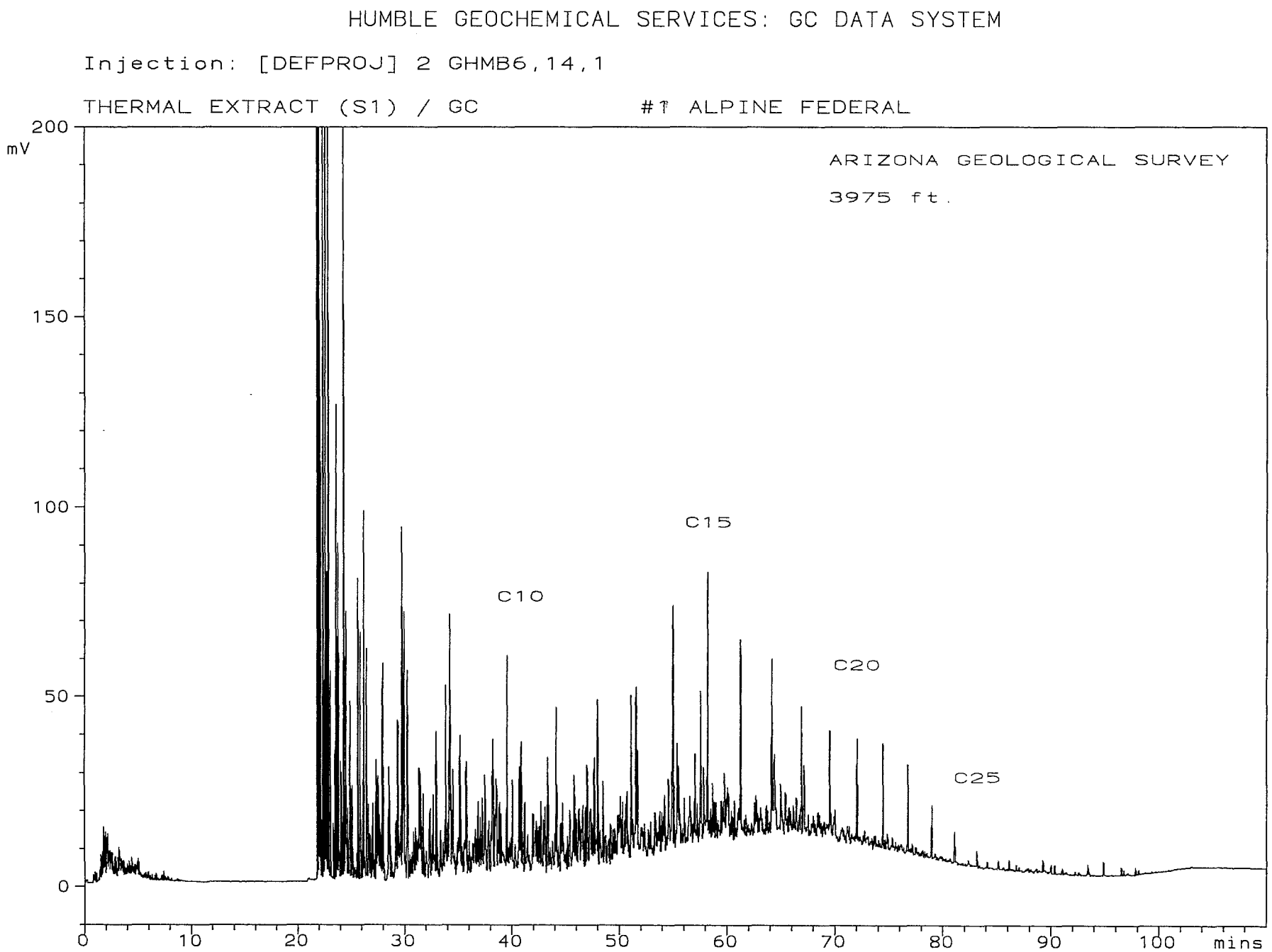


Figure 4.g
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

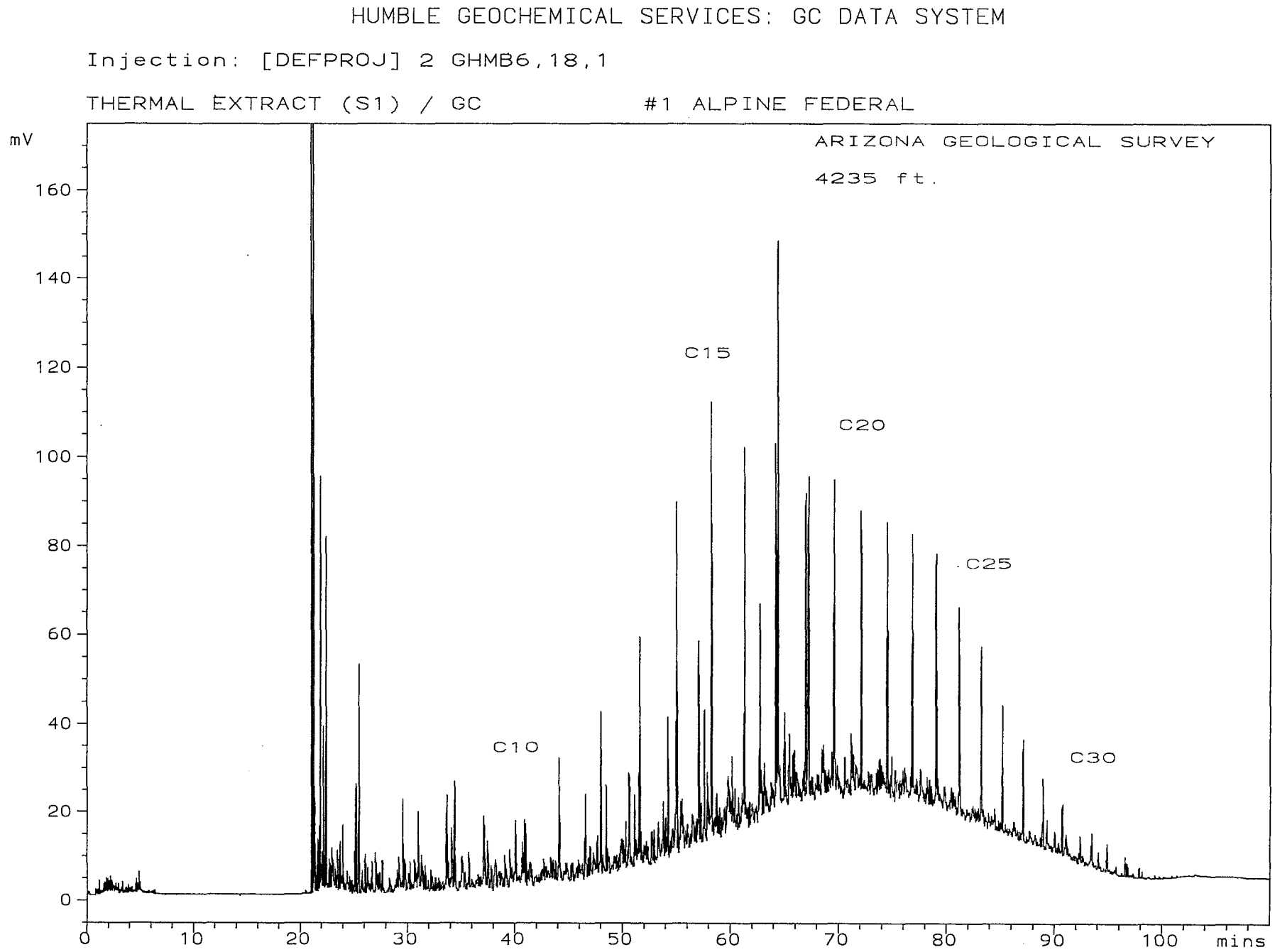


Figure 4.h
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

DEPOSITIONAL ENVIRONMENT & MATURITY
USING TE/GC RATIOS

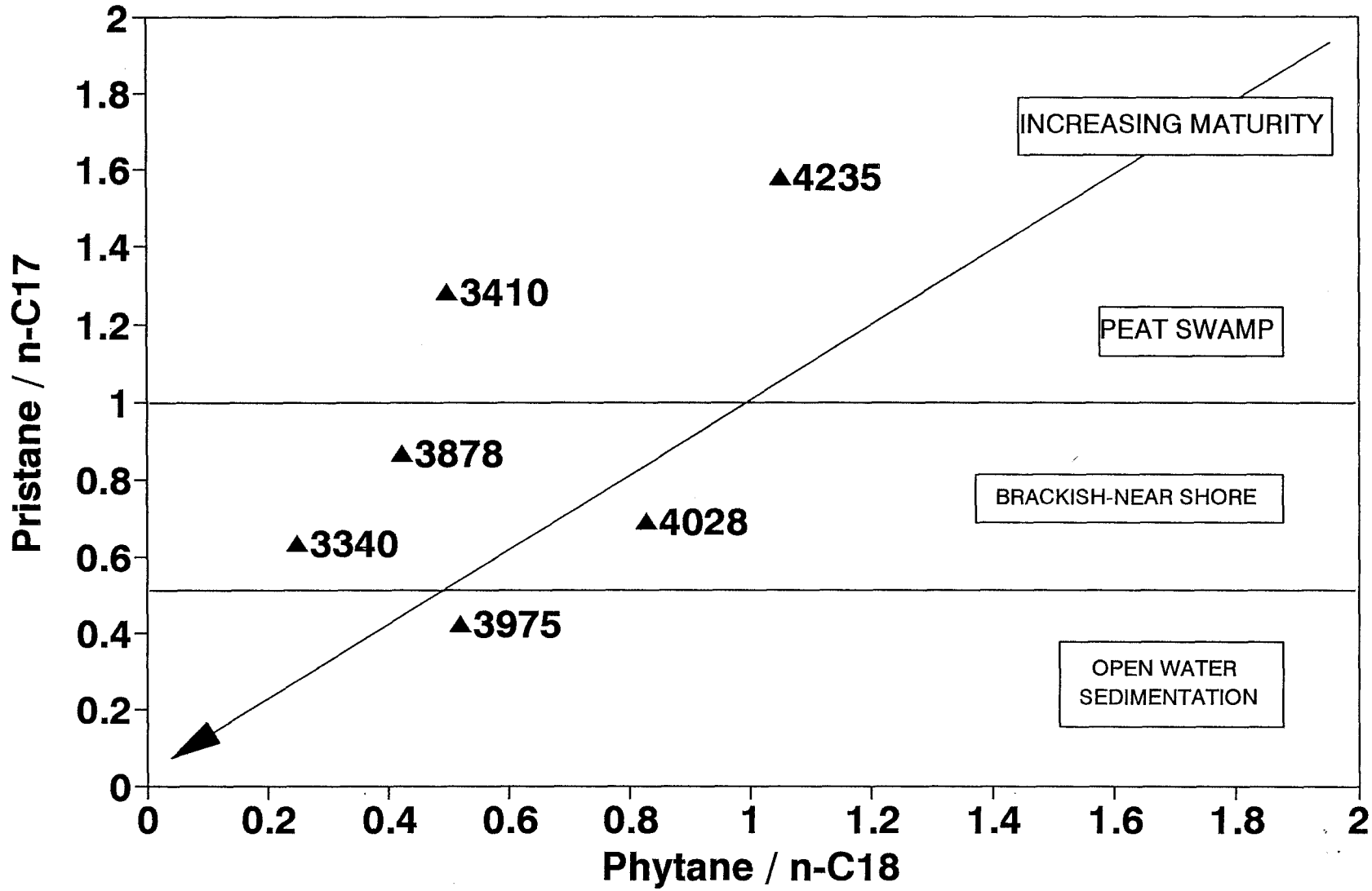


Figure 5
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

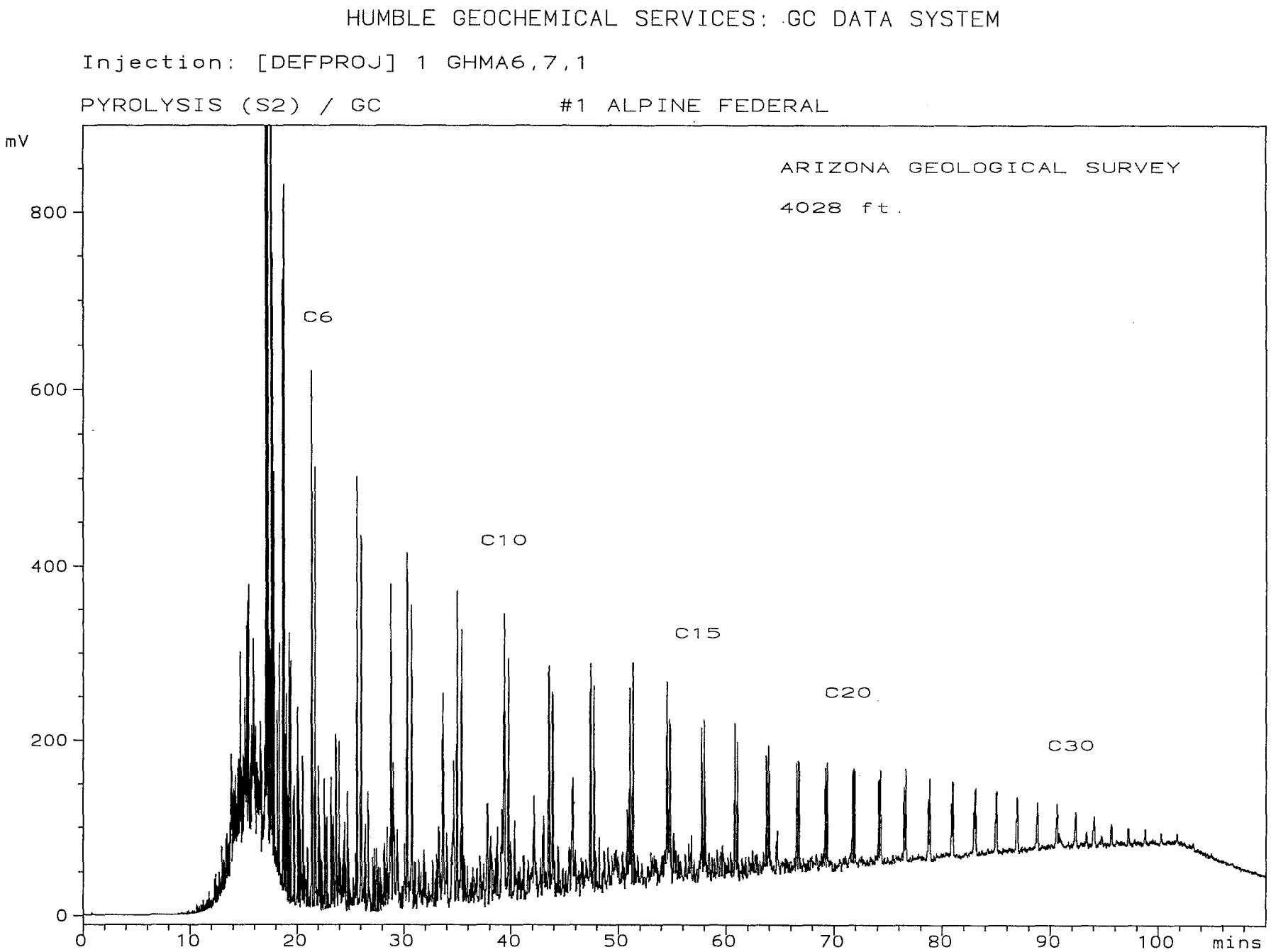


Figure 6.a
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

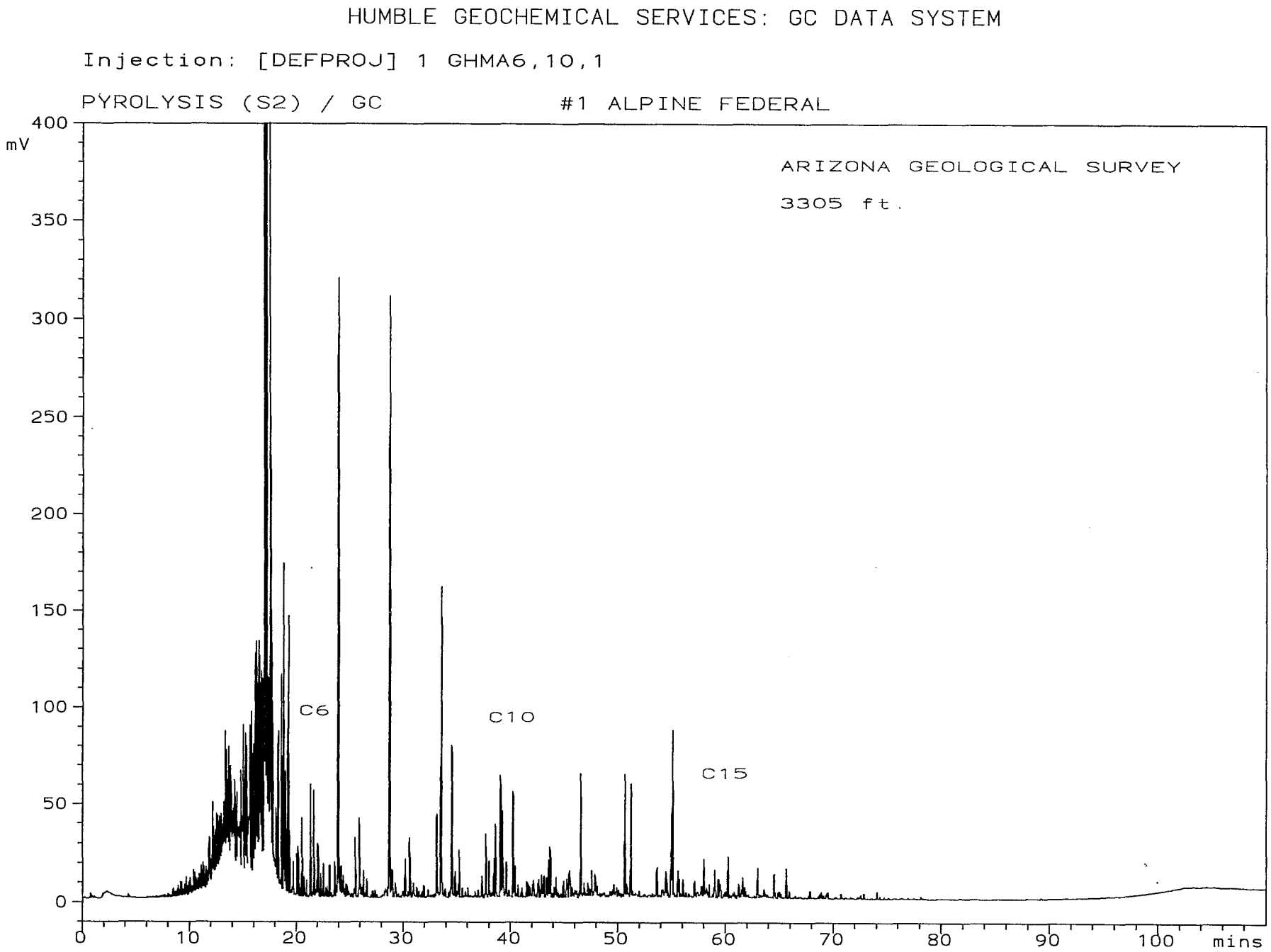


Figure 6.b
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

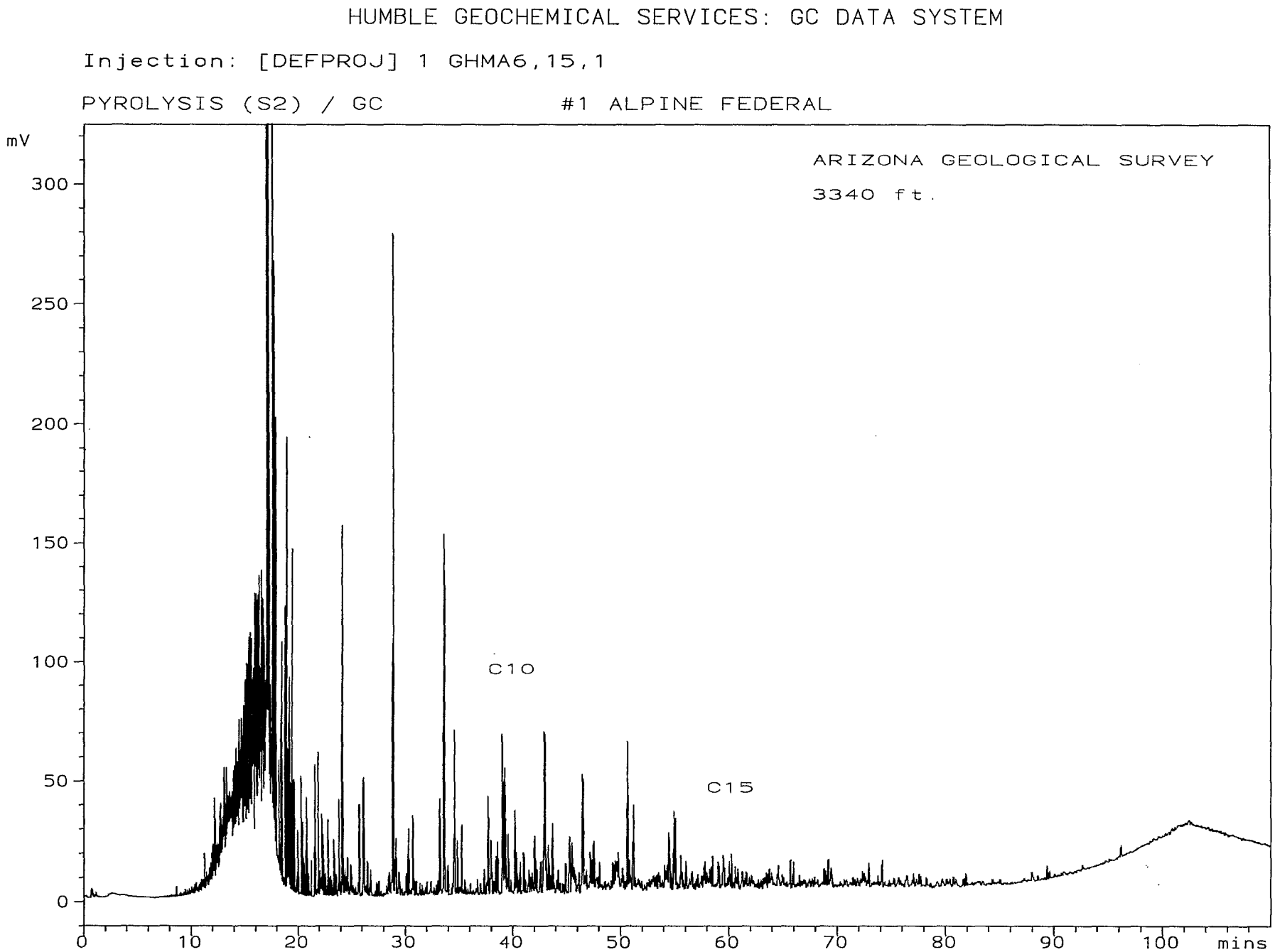


Figure 6.c
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

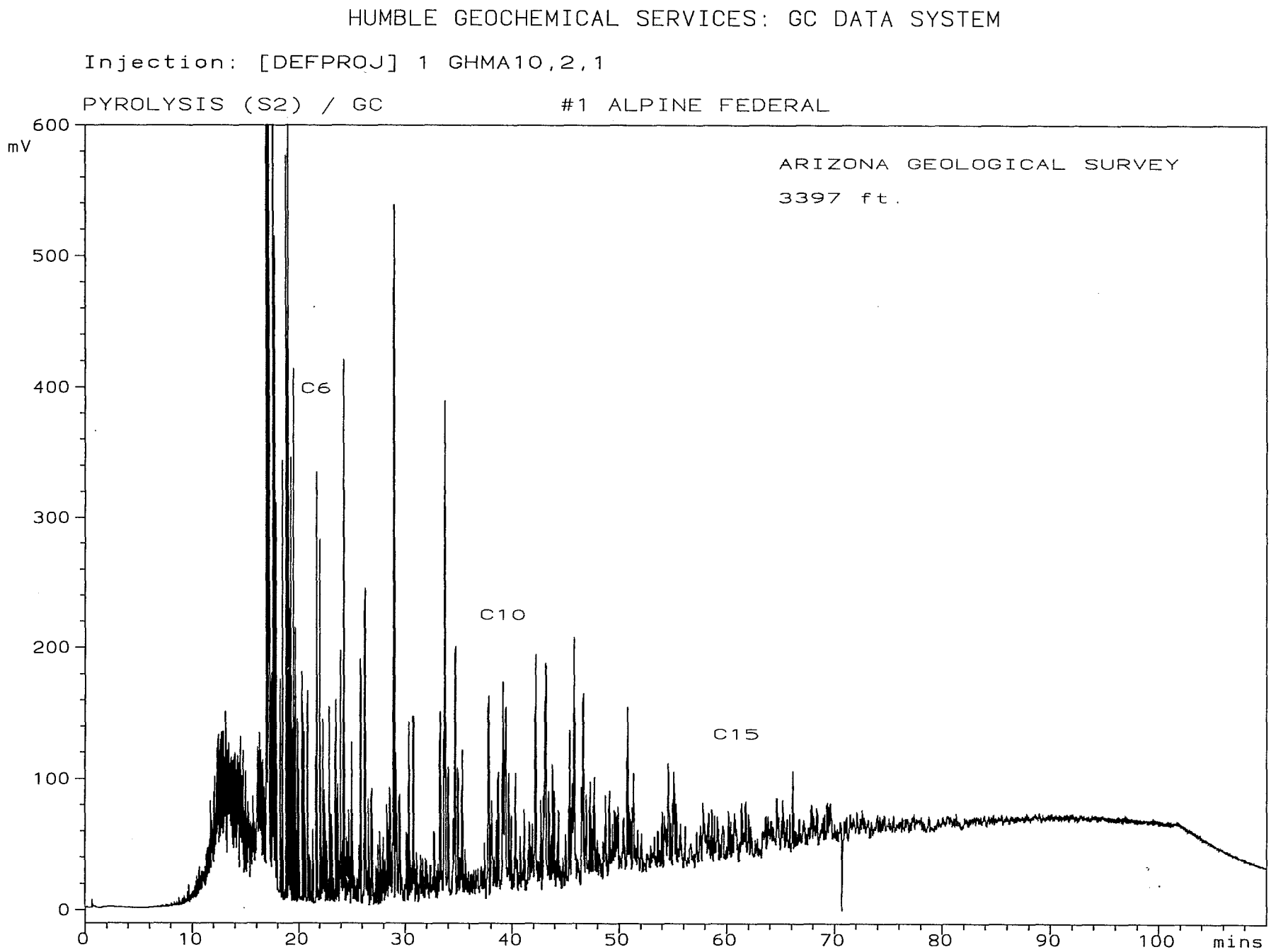


Figure 6.d
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

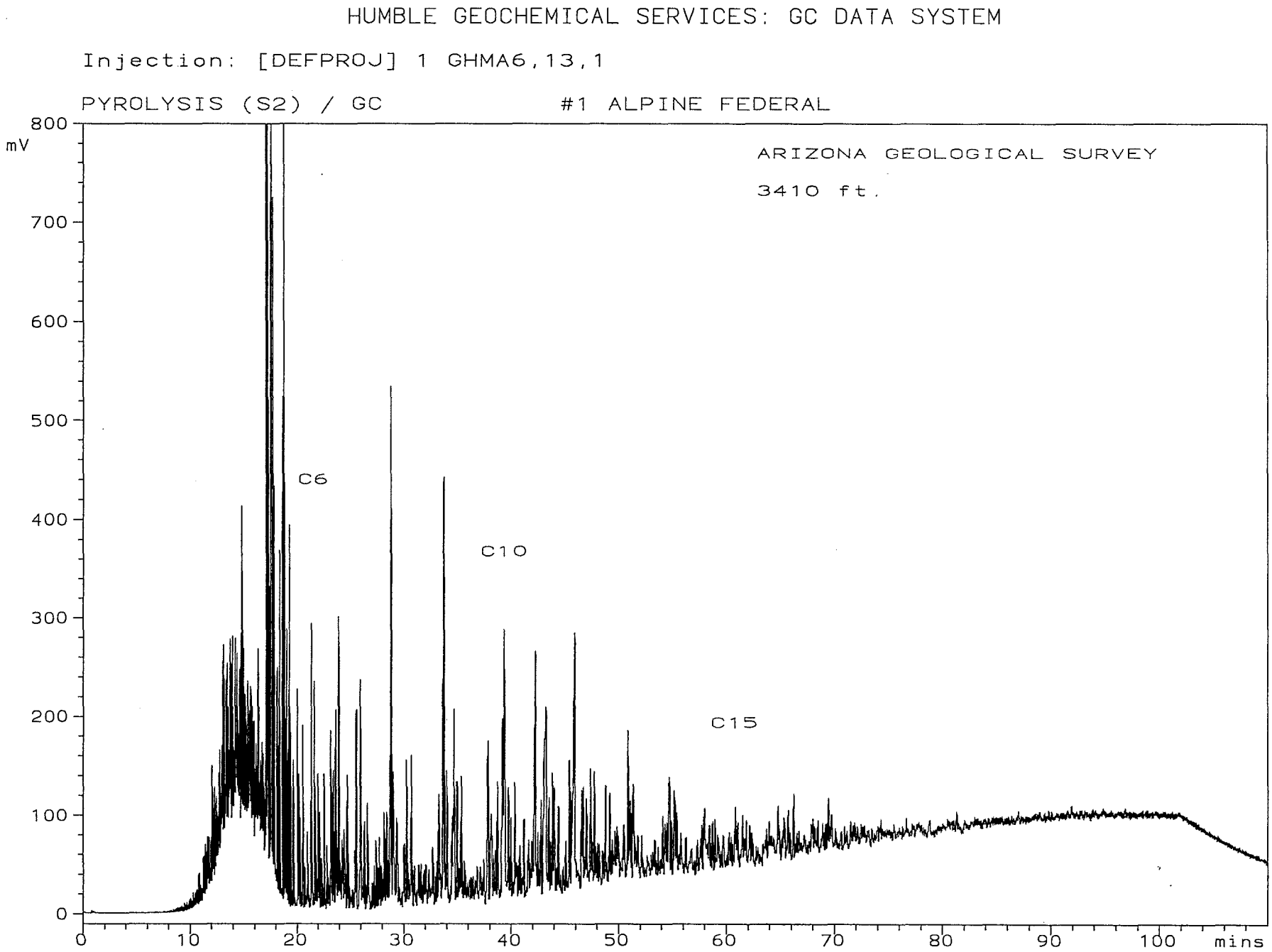


Figure 6.e
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

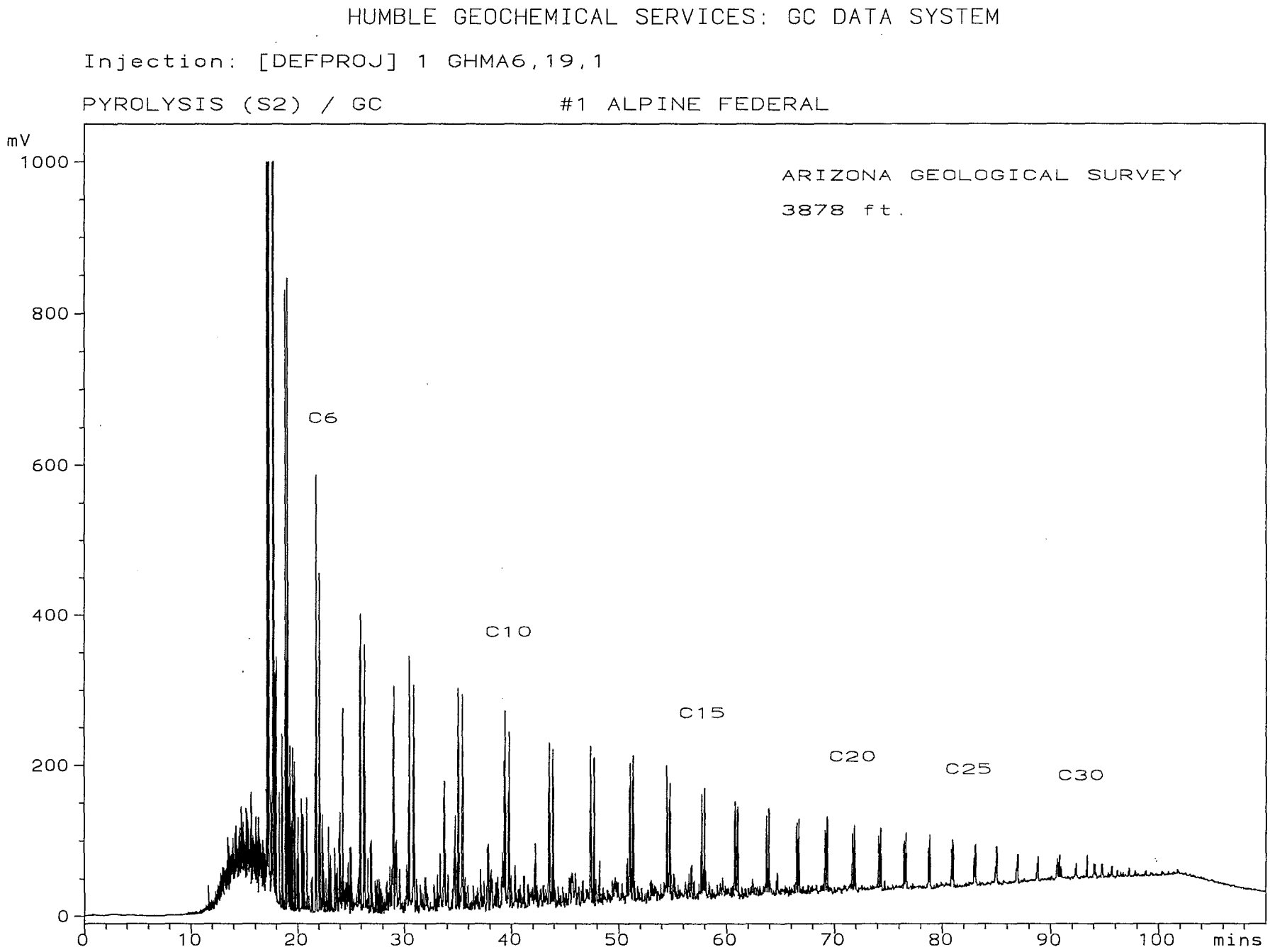


Figure 6.f
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

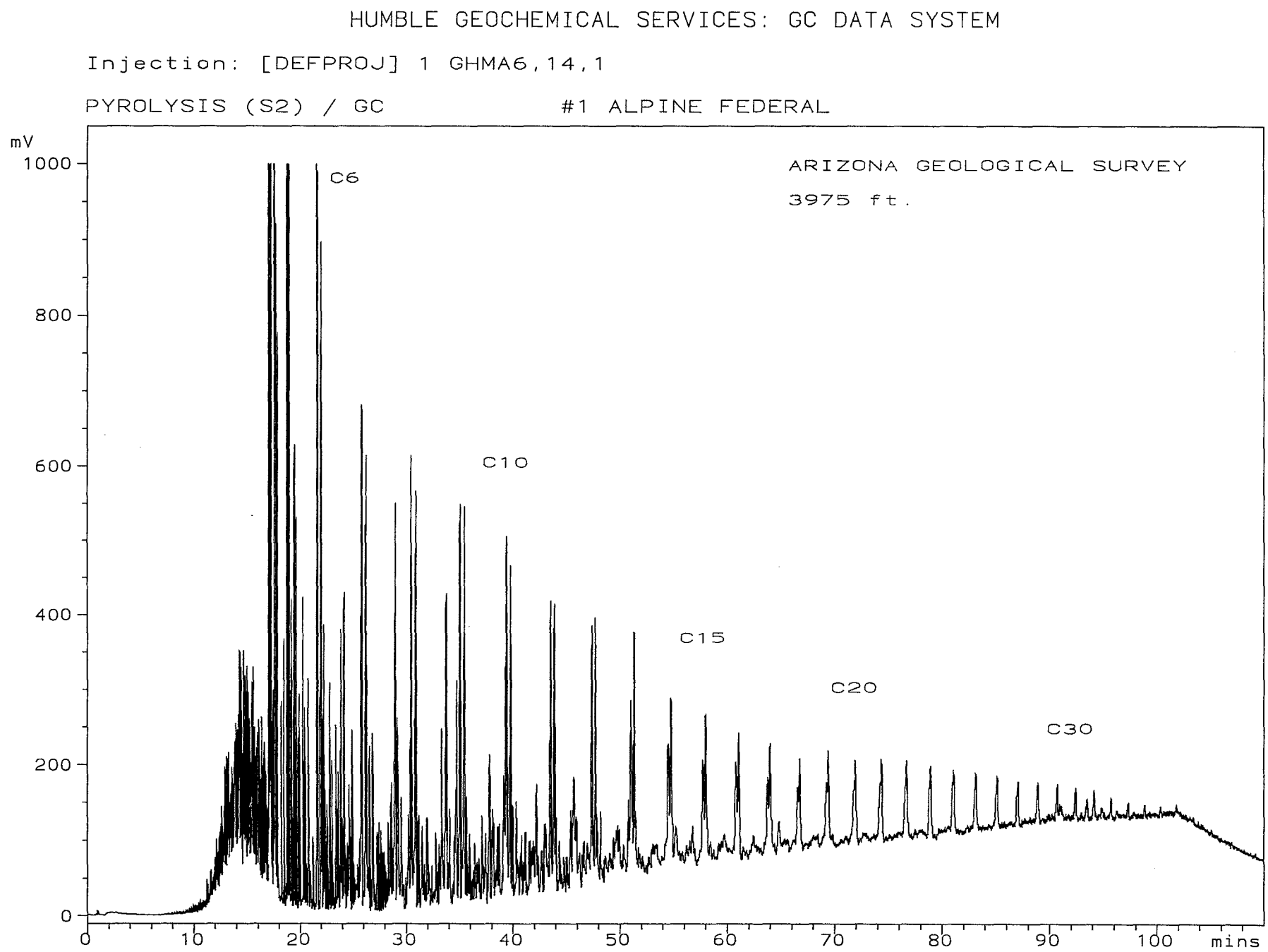


Figure 6.g
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

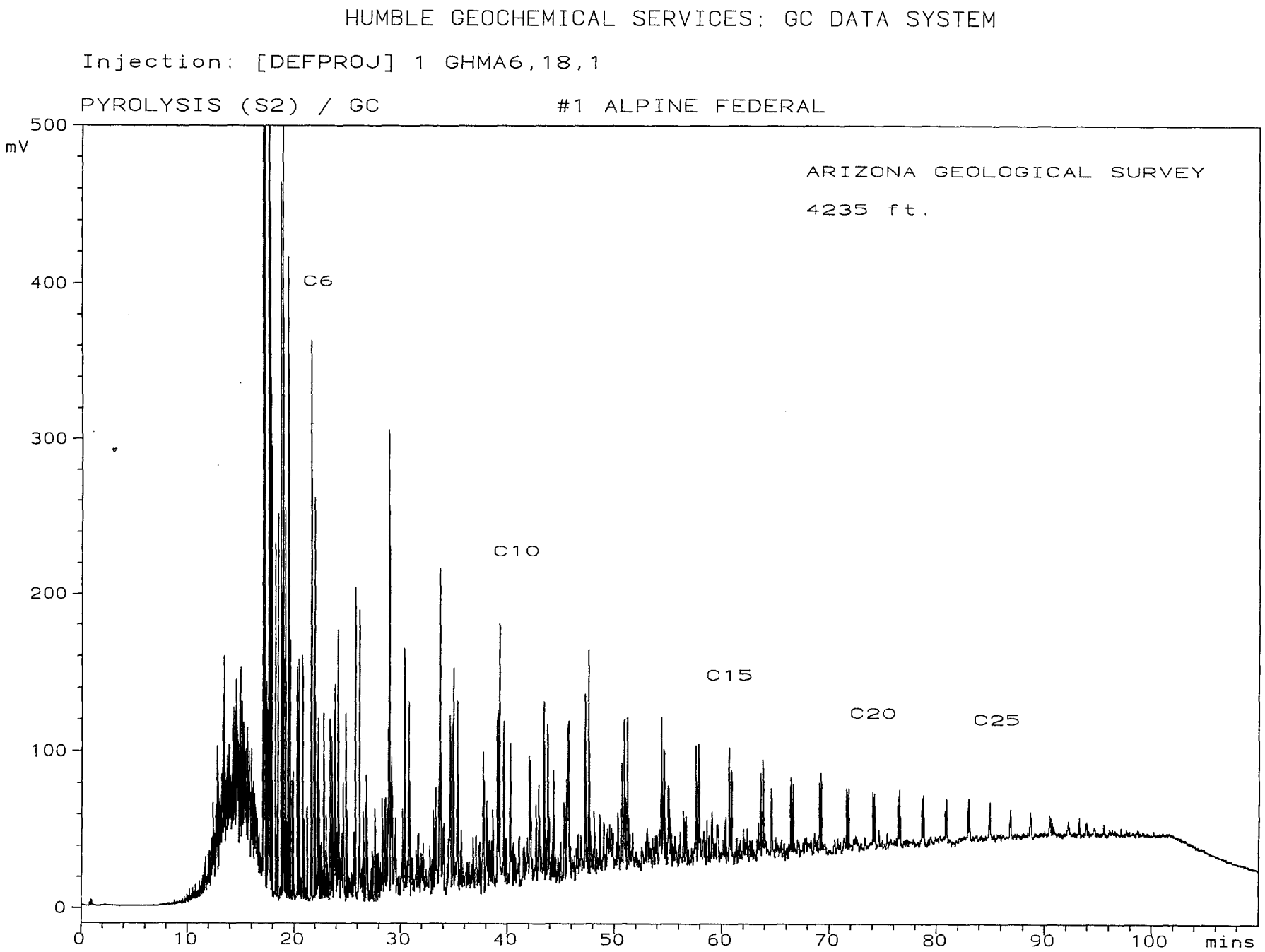
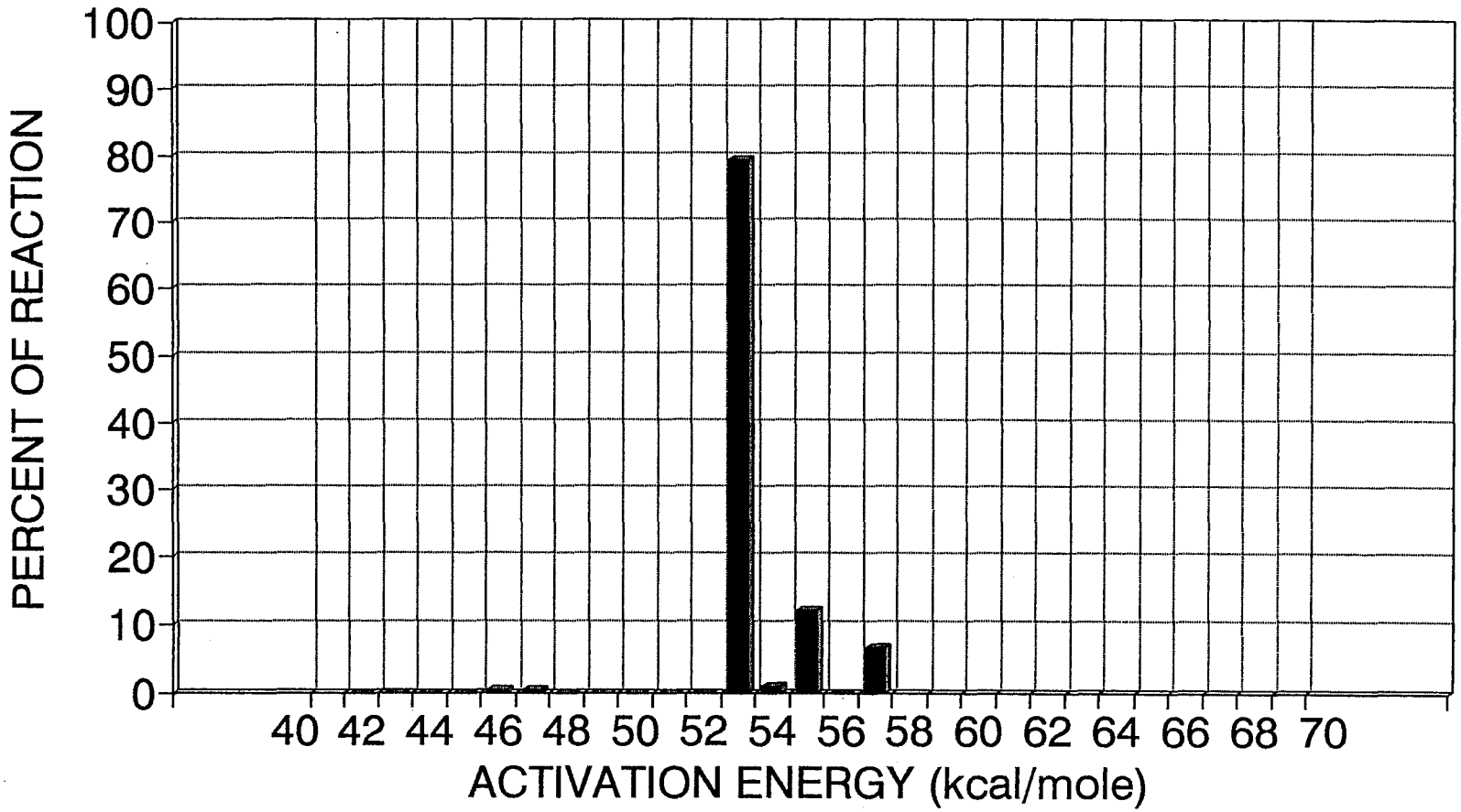


Figure 6.h
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

KINETIC ANALYSIS

1 ALPINE-FEDERAL: CORDUROY FM. 3975 ft.



A = 4.0475E+13/sec

Figure 7
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

GEOLOGICAL MODEL OF KINETIC DATA
TEMPERATURE AND RATE OF OIL GENERATION

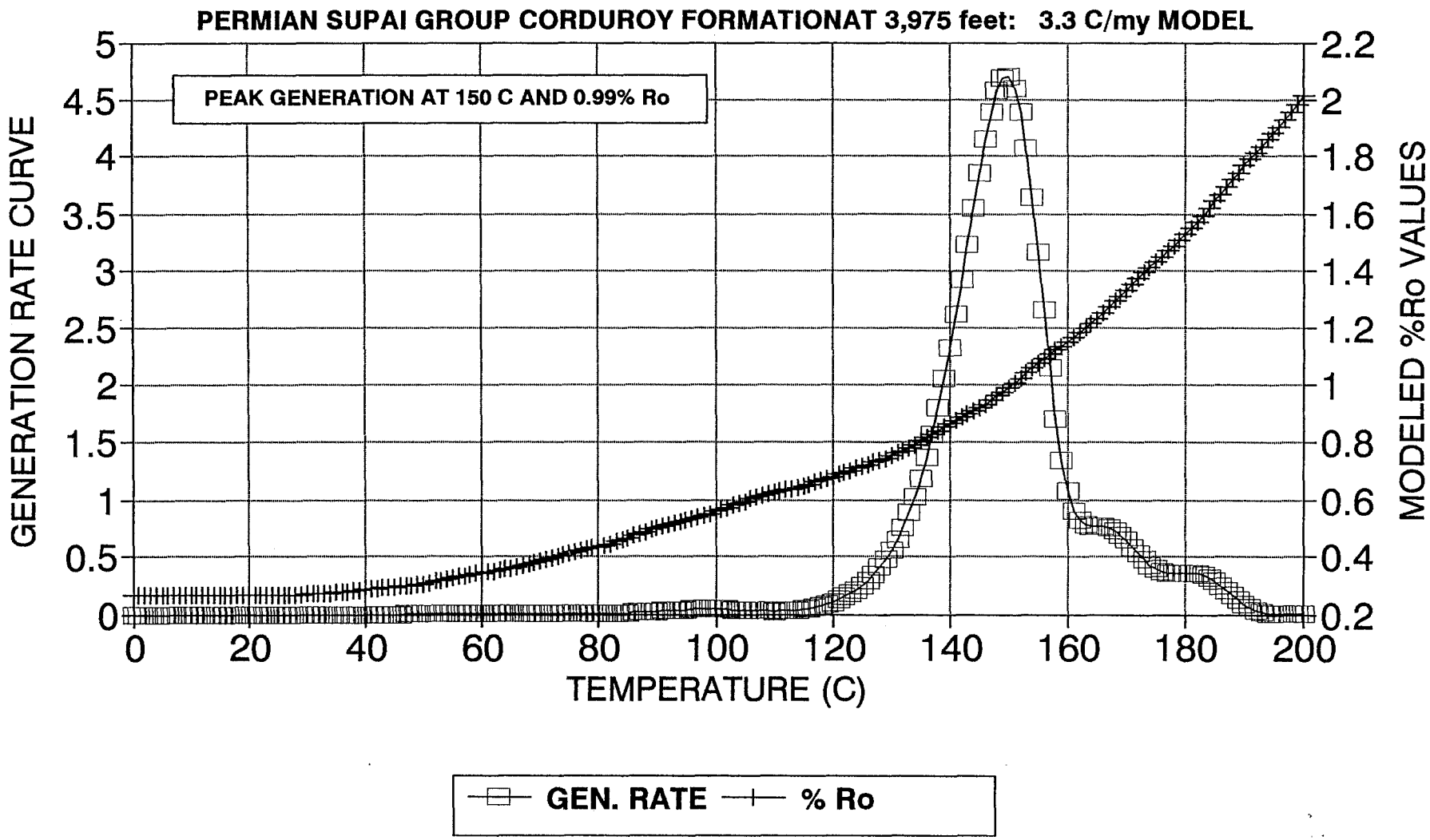


Figure 8
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

GEOLOGICAL MODEL OF KINETIC DATA
TEMPERATURE AND RATE OF OIL GENERATION

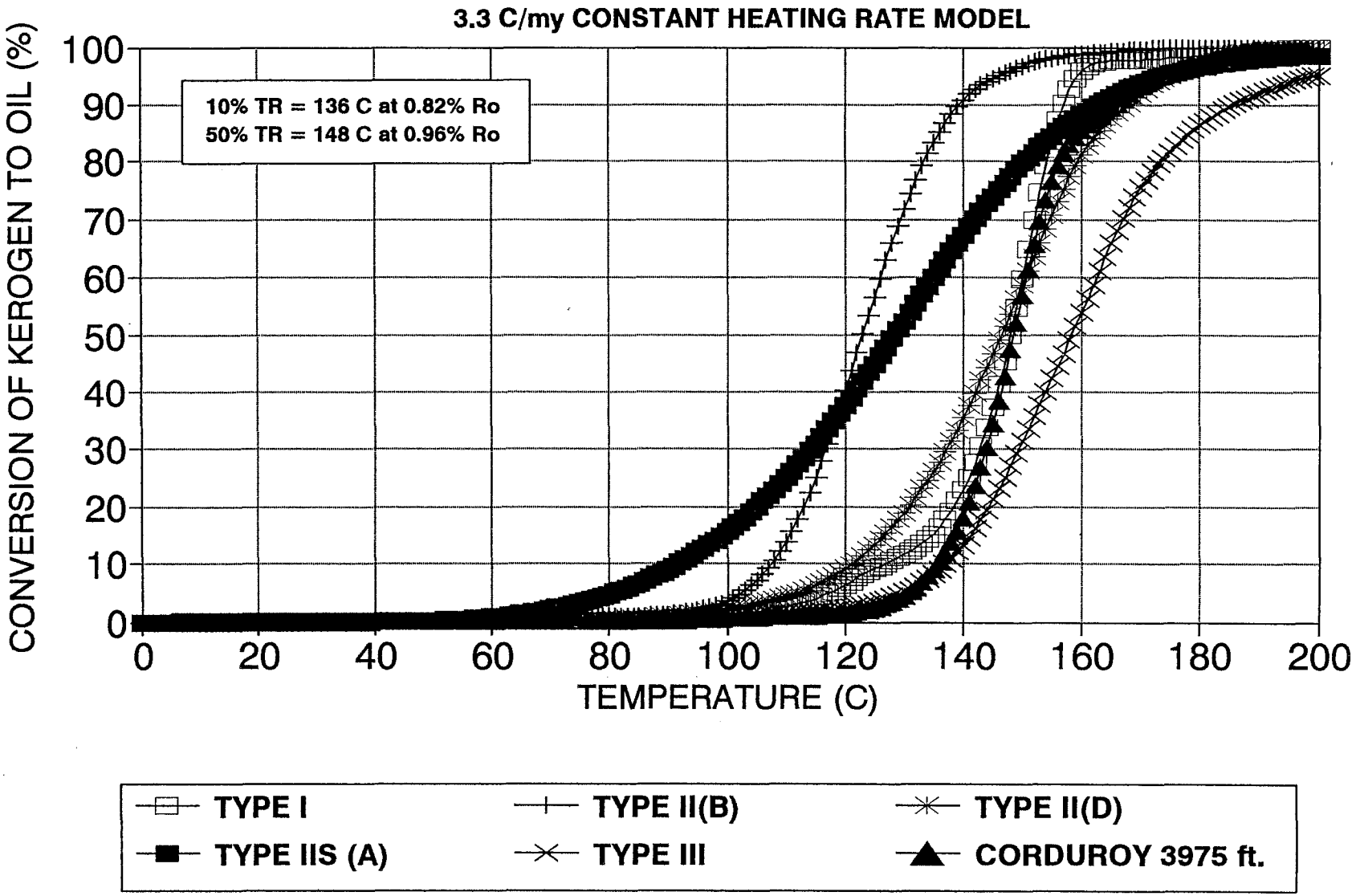


Figure 9
Humble Geochemical Services P.O. Box 789 Humble, Tx 77347

VITRINITE REFLECTANCE AND VISUAL KEROGEN REPORT

Company: Arizona Geological Survey
Tucson, AZ
Attn: Steven L. Rauzi

Well Name: #1 Alpine Federal test
Apache County, Arizona

Sample Type: Core

The following pages are results of kerogen, thermal alteration index (TAI), vitrinite reflectance histograms, and a comparison of source rock quality based on pyrolysis and microscopy. Three samples 3305-4235 ft. (Appendix I.2) were studied in transmitted light and four samples were examined in reflected light (Table II) where they are compared with pyrolysis derived source parameters.

Conclusions

1. Kerogen in the 3305 and 3340 ft. Dakota samples is coaly, and would be a probable gas source at higher maturity level (> 0.70% Ro).

2. Kerogen in the 3878 and 4235 ft. Supai Group samples is dominantly the algal-amorphous type and would be an excellent liquid hydrocarbon source at higher level of maturity (> .55% Ro)

3. Normally vitrinite reflectance increases with increasing depth of burial, yet the samples below 3340 feet, have lower vitrinite reflectance. However, the coaly partings and particles are probably not autchthonous but were formed elsewhere and subsequently deposited in the Dakota sandstone. Fracturing of the coaly bands with subsequent carbonate infilling also suggests sediment transport.

4. Palynofacies indicate the Dakota samples were probably deposited in a near shore beach environment while the algal-amorphous environment was normal anoxic marine.

5. The high hydrogen indexes of 381-392 in the Supai Group cores are confirmed by the bright yellow-orange fluorescence of the algal amorphous kerogen. The fluorescence is not from oil staining as shown on the log, and in high S1 values of 0.96 and 4.25 mg's/gm as the kerogen has been demineralized through HF and HCL acidization.

6. Immaturity of intervals 3878 and 4235 ft. is in agreement with the very high S2 values of 12.29 and 16.66 mg's hydrocarbons/gm rock, respectively, indicative of only minor conversion of kerogen to petroleum.

Appendix 1.2

THERMAL ALTERATION, KEROGEN TYPE, AND PALYNOFACIES DATA

DATE 5-26-94

WELL #1 Alpine Fed.

LOCATION Ariz.

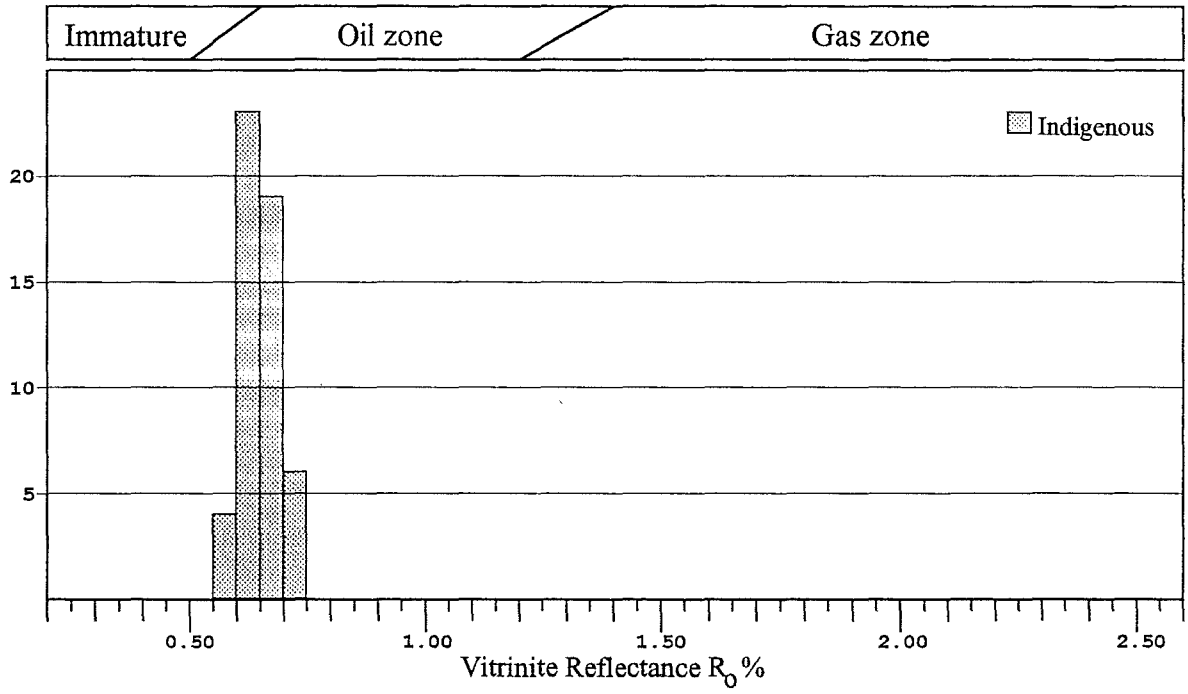
DEPTH ☒ FT ☐ M		COLOR								THERMAL ALTERATION INDEX (TAI)								% SOURCE MATERIAL							PRESERVATION			RECOVERY		PALYNOFACIES				FLUORESCENCE			R_o	REMARKS
		GREENISH LIGHT YELLOW	YELLOW	YELLOW - ORANGE	ORANGE - BROWN	LIGHT BROWN	BROWN	DARK BROWN - DARK GRAY	DARK GRAY - BLACK	1 UNALTERED	1+	2 SLIGHT ALTERATION	2+	3 MODERATE ALTERATION	3+	4 STRONG ALTERATION	4+	5 SEVERE ALTERATION	AMORPHOUS DEBRIS	FINELY DISSEM. O.M.	HERB. PLANT DEBRIS	WOODY PLANT DEBRIS	COALY FRAGMENTS	ALGAL DEBRIS	PALYNOMORPHS	GOOD	FAIR	POOR	VERY POOR RECOVERY	BARREN OF O.M.	MARINE	NEARSHORE - BRACKISH	CONTINENTAL	LACUSTRINE	UNKNOWN	YELLOW	YELLOW - ORANGE	ORANGE	RED - ORANGE	REFLECTANCE MEAN Ro %	
Dakota	3305			X									X									100		N		X					X									No fluor.
Supai	3878		X									X						95				5		N		X				X						X			0.42	GROUND MASS & PARTICLES
"	4235		X									X						97				3		R				X		X						X	X		0.40	" " "
																																								90% of OM fluoresces

Palynomorph Key
A = Abundant
C = Common
V = Present
R = Rare
N = None Seen

HUMBLE GEOCHEMICAL SERVICES

12 - 8 - 93

Customer: ***ARIZONA GEOL. SURVEY***
Well name: ***#1 ALPINE FEDERAL***
Sample ID: ***PKD. COAL***
Mean depth (ft): ***3305***
Sample type: ***CUTTINGS***



Indigenous population statistics

Mean: 0.65 Min: 0.55 Max: 0.75 Std. Dev.: 0.03 Count: 52

Total population statistics

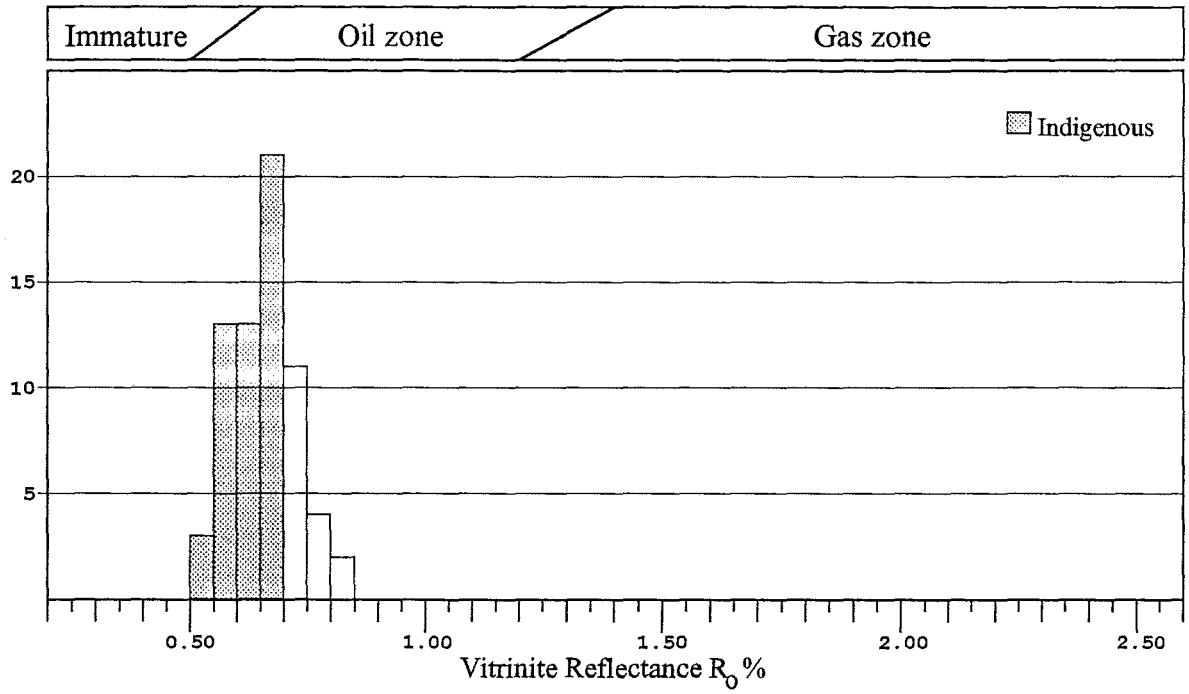
Mean: 0.65 Min: 0.58 Max: 0.71 Std. Dev.: 0.03 Count: 52

01 - 0.58 <	21 - 0.63 <	41 - 0.68 <
02 - 0.59 <	22 - 0.63 <	42 - 0.68 <
03 - 0.59 <	23 - 0.63 <	43 - 0.68 <
04 - 0.59 <	24 - 0.64 <	44 - 0.69 <
05 - 0.60 <	25 - 0.64 <	45 - 0.69 <
06 - 0.61 <	26 - 0.64 <	46 - 0.69 <
07 - 0.61 <	27 - 0.64 <	47 - 0.70 <
08 - 0.61 <	28 - 0.65 <	48 - 0.70 <
09 - 0.62 <	29 - 0.65 <	49 - 0.70 <
10 - 0.62 <	30 - 0.65 <	50 - 0.70 <
11 - 0.62 <	31 - 0.65 <	51 - 0.70 <
12 - 0.62 <	32 - 0.66 <	52 - 0.71 <
13 - 0.62 <	33 - 0.66 <	
14 - 0.62 <	34 - 0.66 <	
15 - 0.62 <	35 - 0.67 <	
16 - 0.62 <	36 - 0.67 <	
17 - 0.63 <	37 - 0.68 <	
18 - 0.63 <	38 - 0.68 <	
19 - 0.63 <	39 - 0.68 <	
20 - 0.63 <	40 - 0.68 <	

Note: Reflectance values rounded to nearest hundredth, [<] indicates indigenous reflectance value

HI&S Ref: 94-6458A.RO/JB ***Humble Geochemical Services*** Thu Jun 16 1994/2.0

Customer: ***ARIZONA GEOL. SURVEY***
Well name: ***#1 ALPINE FEDERAL***
Sample ID: ***PKD. COAL***
Mean depth (ft): ***3340***
Sample type: ***CORE***



Indigenous population statistics

Mean: 0.62 Min: 0.53 Max: 0.69 Std. Dev.: 0.04 Count: 50

Total population statistics

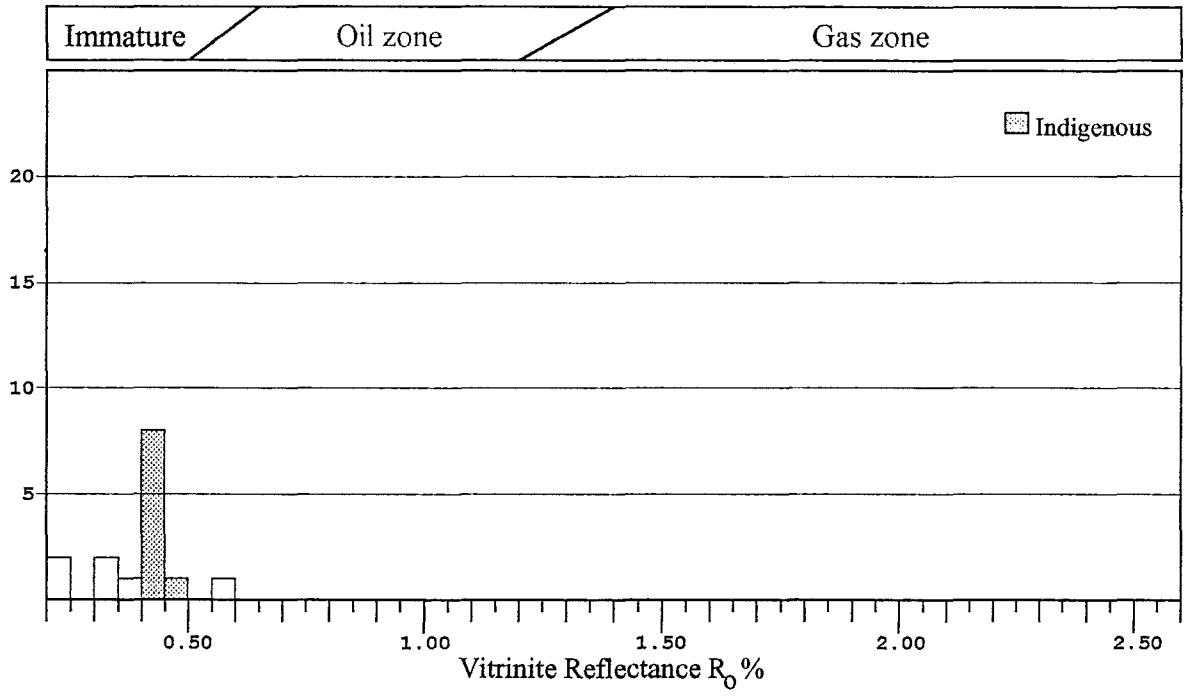
Mean: 0.65 Min: 0.53 Max: 0.80 Std. Dev.: 0.06 Count: 67

01 - 0.53 <	21 - 0.62 <	41 - 0.67 <	61 - 0.74
02 - 0.54 <	22 - 0.62 <	42 - 0.67 <	62 - 0.75
03 - 0.54 <	23 - 0.62 <	43 - 0.67 <	63 - 0.75
04 - 0.56 <	24 - 0.63 <	44 - 0.67 <	64 - 0.76
05 - 0.56 <	25 - 0.63 <	45 - 0.67 <	65 - 0.77
06 - 0.57 <	26 - 0.63 <	46 - 0.67 <	66 - 0.80
07 - 0.57 <	27 - 0.64 <	47 - 0.68 <	67 - 0.80
08 - 0.57 <	28 - 0.64 <	48 - 0.68 <	
09 - 0.57 <	29 - 0.64 <	49 - 0.68 <	
10 - 0.57 <	30 - 0.65 <	50 - 0.69 <	
11 - 0.58 <	31 - 0.65 <	51 - 0.70	
12 - 0.58 <	32 - 0.65 <	52 - 0.70	
13 - 0.58 <	33 - 0.65 <	53 - 0.71	
14 - 0.58 <	34 - 0.66 <	54 - 0.72	
15 - 0.59 <	35 - 0.66 <	55 - 0.72	
16 - 0.59 <	36 - 0.66 <	56 - 0.72	
17 - 0.60 <	37 - 0.66 <	57 - 0.72	
18 - 0.61 <	38 - 0.66 <	58 - 0.73	
19 - 0.62 <	39 - 0.66 <	59 - 0.73	
20 - 0.62 <	40 - 0.66 <	60 - 0.73	

Note: Reflectance values rounded to nearest hundredth, [<] indicates indigenous reflectance value

HI&S Ref: 94-64-61.RO/JB ***Humble Geochemical Services*** Fri Jun 17 1994/2.0

Customer: ***ARIZON GEOL. SURVEY***
Well name: ***#1 ALPINE FEDERAL***
Sample ID: ***SUPAI GRP.***
Mean depth (ft): ***3878***
Sample type: ***CORE***



Indigenous population statistics

Mean: 0.42 Min: 0.40 Max: 0.54 Std. Dev.: 0.02 Count: 09

Total population statistics

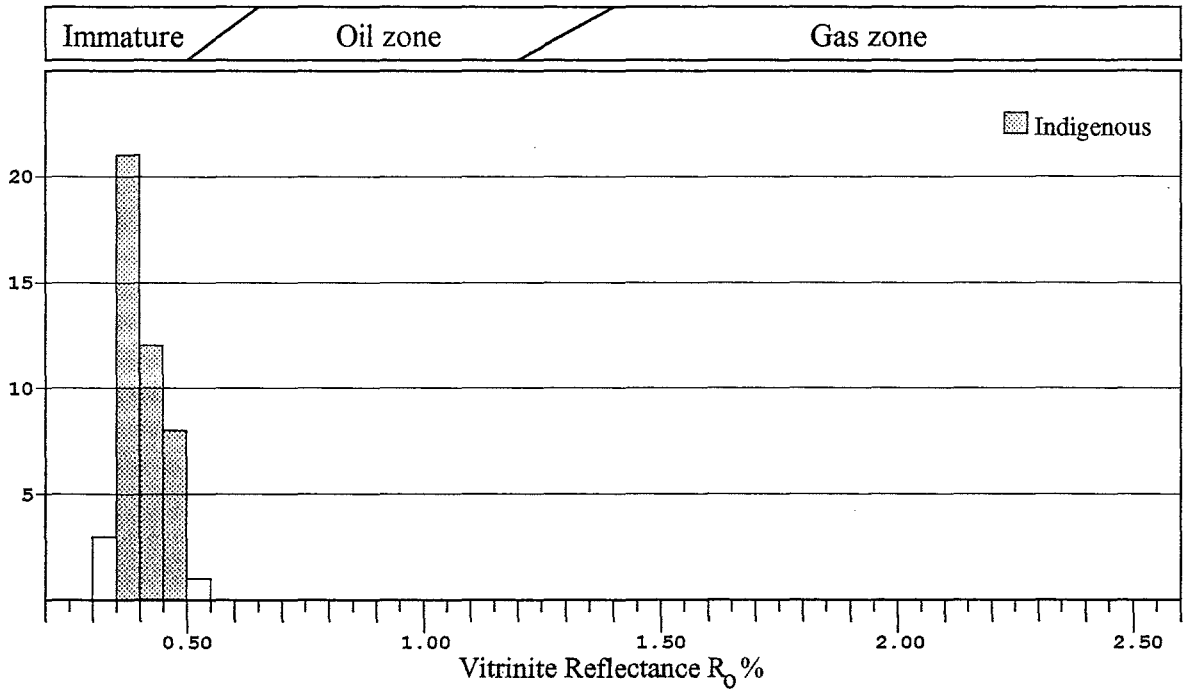
Mean: 0.39 Min: 0.23 Max: 0.55 Std. Dev.: 0.08 Count: 15

01 - 0.23
02 - 0.24
03 - 0.31
04 - 0.32
05 - 0.37
06 - 0.40 <
07 - 0.40 <
08 - 0.40 <
09 - 0.41 <
10 - 0.43 <
11 - 0.43 <
12 - 0.43 <
13 - 0.44 <
14 - 0.45 <
15 - 0.55

Note: Reflectance values rounded to nearest hundredth, [<] indicates indigenous reflectance value

HI&S Ref: 94-64-90.RO/JB *Humble Geochemical Services* Mon Jun 20 1994/2.0

Customer: ***ARIZONA GEOL. SURVEY***
Well name: ***#1 ALPINE FEDERAL***
Sample ID: ***FT. APACHE***
Mean depth (ft): ***4235***
Sample type: ***CORE***



Indigenous population statistics

Mean: 0.40 Min: 0.35 Max: 0.49 Std. Dev.: 0.04 Count: 41

Total population statistics

Mean: 0.40 Min: 0.32 Max: 0.50 Std. Dev.: 0.05 Count: 45

01 - 0.32	21 - 0.38 <	41 - 0.48 <
02 - 0.33	22 - 0.38 <	42 - 0.48 <
03 - 0.34	23 - 0.38 <	43 - 0.48 <
04 - 0.35 <	24 - 0.39 <	44 - 0.49 <
05 - 0.35 <	25 - 0.40 <	45 - 0.50
06 - 0.35 <	26 - 0.40 <	
07 - 0.35 <	27 - 0.41 <	
08 - 0.35 <	28 - 0.41 <	
09 - 0.36 <	29 - 0.41 <	
10 - 0.36 <	30 - 0.41 <	
11 - 0.36 <	31 - 0.42 <	
12 - 0.36 <	32 - 0.42 <	
13 - 0.36 <	33 - 0.42 <	
14 - 0.36 <	34 - 0.42 <	
15 - 0.37 <	35 - 0.44 <	
16 - 0.37 <	36 - 0.44 <	
17 - 0.37 <	37 - 0.45 <	
18 - 0.37 <	38 - 0.45 <	
19 - 0.38 <	39 - 0.45 <	
20 - 0.38 <	40 - 0.47 <	

Note: Reflectance values rounded to nearest hundredth, [<] indicates indigenous reflectance value

HI&S Ref: 94-64119.RO/JB ***Humble Geochemical Services*** Fri Jun 17 1994/2.0

Humble Geochemical Services
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Generalized Chemical and Physical Characteristics of Kerogen

(when immature)

KEROGEN TYPE	HYDROGEN INDEX	OXYGEN INDEX	ELEMENTAL H/C	ORGANIC MATTER	DEPOSITIONAL ENVIRONMENT	INTERNAL STRUCTURES	PRINCIPAL PRODUCTS
I	700 - 1000+	10 - 40	>= 1.4	ALGAL; AMORPHOUS; RARE TERRESTRIAL	ANOXIC (SALINE), LACUSTRINE; RARE MARINE	FINELY LAMINATED	OIL
II	350 - 700	20 - 60	1.2 - 1.4	ALGAL;AMORPHOUS; COMMON TERRESTRIAL	ANOXIC; MARINE	LAMINATED, WELL BEDDED	OIL
II / III	200 - 350	40 - 80	1 - 1.2	MIXED MARINE, TERRESTRIAL	VARIABLE; DELTAIC	POORLY BEDDED	MIXED OIL/GAS
III	50 - 200	50 - 150	0.7 - 1.0	TERRESTRIAL, MOSTLY "VITRINITES"; DEGRADED ALGAL	MILDLY OXIC; SHELF/SLOPE; COALS	POORLY BEDDED; BIOTURBATED	GAS
IV	< 50	20 - 200	0.4 - 0.7	HIGHLY OXIDIZED; REWORKED	HIGHLY OXIC; ANYWHERE	MASSIVE; BIOTURBATED	DRY GAS

Modified from Jones, R. W., 1984, Comparison of Carbonate and Shale Source Rocks,pp. 163-180, in Petroleum Geochemistry and Source Rock Potential of Carbonate Rocks, AAPG Studies in Geology 18, J. Palacas, ed.