Chemometric Recognition of Genetically Distinct Oil Families in the Los Angeles Basin*

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Search and Discovery Article #41149 (2013)**
Posted July 22, 2013

*Adapted from oral presentation given at 2013 Pacific Section AAPG, SEG and SEPM Joint Technical Conference, Monterey, California, April 19-25, 2013

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Abstract

Multivariate statistical analysis (chemometrics) of selected source-related biomarker and stable carbon isotope ratios for 112 nonbiodegraded or mildly biodegraded crude oil samples from the prolific Los Angeles basin identifies five tribes and a total of 12 genetically distinct oil families. These families occur in different parts of the basin and exhibit different bulk properties, such as API gravity, sulfur, and metal content that are principally controlled by source rock organofacies rather than secondary processes, such as thermal maturity or biodegradation. Stable carbon isotope data for saturate and aromatic fractions of the samples suggest Neogene source rock, although not necessarily all from the basal Mohnian nodular shale unit of the Modelo Formation. Biomarker ratios allow indirect assessment of the character to the source rock for each family. For example, tribes 1 and 2 straddle the Central Trough to the east of the Newport-Inglewood Fault Zone and show evidence of elevated clastic and higher-plant input (e.g., elevated C24/C23 tricyclic terpanes and oleanane, respectively). Some families clearly originated from source rock in different depocenters on opposite sides of the Newport-Inglewood Fault Zone and from different stratigraphic intervals. For example, unlike tribes 1 and 2, tribe 5 occurs west of the Newport-Inglewood Fault Zone and shows evidence of a more distal, clay-poor source rock (e.g., lower C24/C23 tricyclic terpanes and oleanane, elevated steranes/hopanes and bisnorhopane). As another example, tribe 5 oils occur in deeper intervals (9007-10,480 ft) than tribe 3 oils (3531-6842 ft) in the Wilmington field. The 112 crude oil samples were used as a training set to build a chemometric decision tree, which allowed classification of nearly 50 additional samples that were affected to varying degrees by severe thermal maturation or biodegradation.

Selected References

Blake, G.H., 1991, Review of the Neogene biostratigraphy and stratigraphy of the Los Angeles basin and implications for basin evolution: AAPG Memoir 52, p. 135-184.

Jeffrey, A.W.A., H.M. Alimi, and P.D. Jenden, 1991, Geochemistry of Los Angeles basin oil and gas systems: AAPG Memoir 52, p. 197-219.

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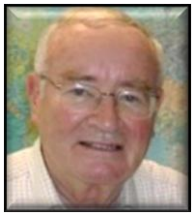
Sedimentology and Biogeochemistry of the Monterey Formation and Modern Upwelling Sediments: a Session Dedicated to Bob Garrison



April 21-25, 2013
Monterey, CA

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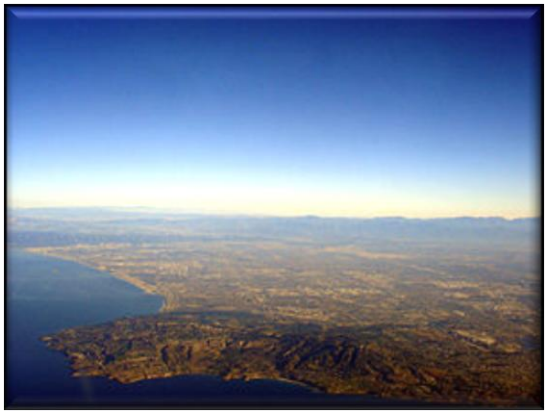
Acknowledgements

- *Tess Menotti (maps of sample locations)*
- *Tom Wright (discussions of LA basin stratigraphy)*
- *Les Magoon (general discussions)*

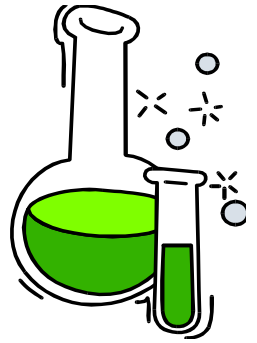
Significant Characteristics of the Los Angeles Basin

- **Richest basin in the world based on amount of petroleum relative to volume of sedimentary fill.**
- **Classic model of transform-margin basin.**
- **Since Brea-Olinda in 1880, 67 fields were discovered; three supergiants include Wilmington, Long Beach, and Huntington Beach.**
- **Little exploration since the early 1970's.**
- **Significant potential likely remains in deep, especially offshore areas.**

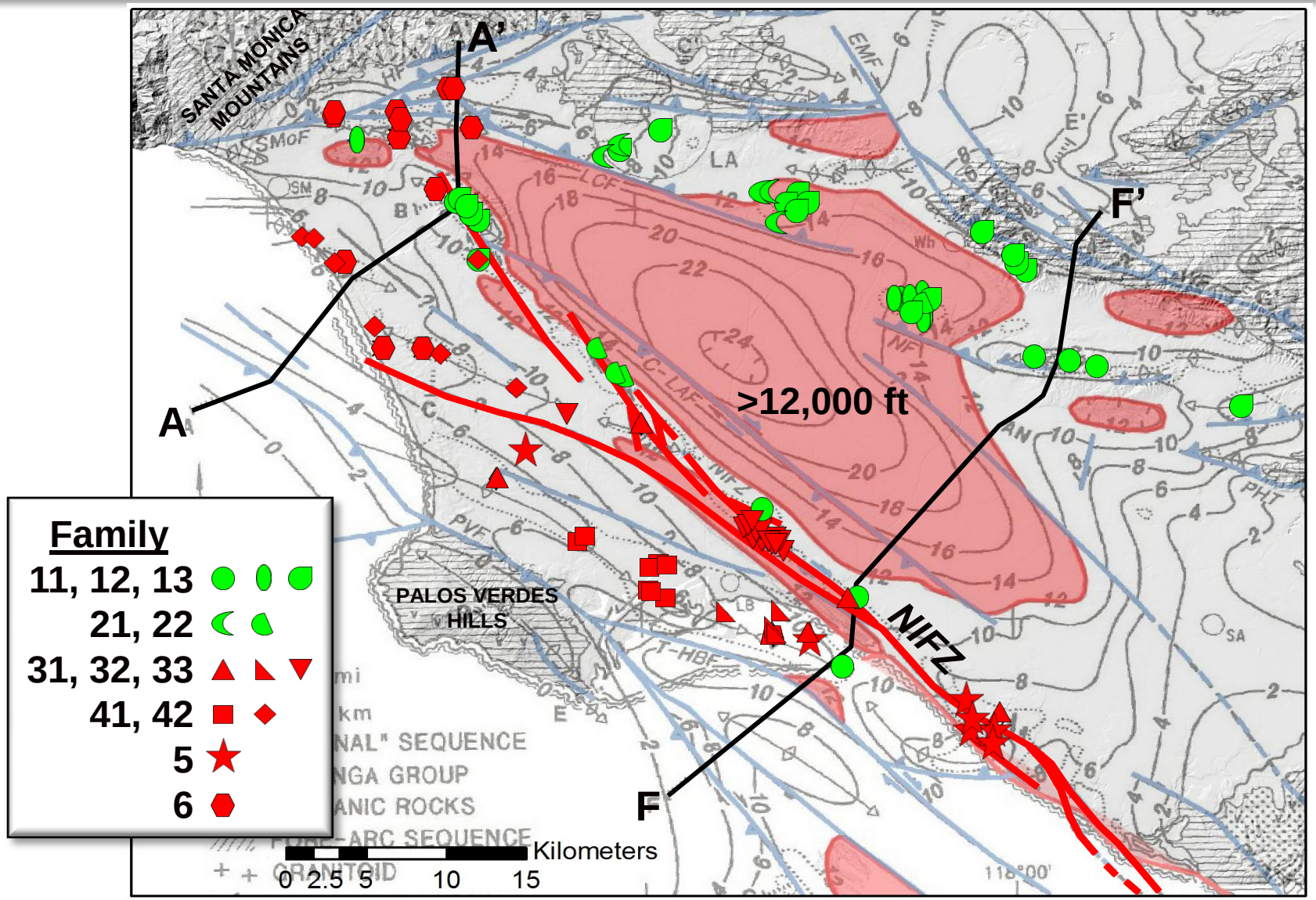


Purpose of the Los Angeles Basin Study

- **Measure biomarker and isotope ratios for ~150 crude oil samples from the basin to evaluate genetic relationships.**
- **Assess the extent of biodegradation for each sample to identify a "training set" where source-related biomarker or isotope ratios are unaffected.**
- **Identify oil families; create a chemometric (multivariate statistics) decision tree to classify new samples.**
- **Map the distribution of oil families; use biomarker and isotope ratios to infer their source rock organofacies.**



Map Shows Families and Base Mohnian (~14 Ma) >12,000 Ft.



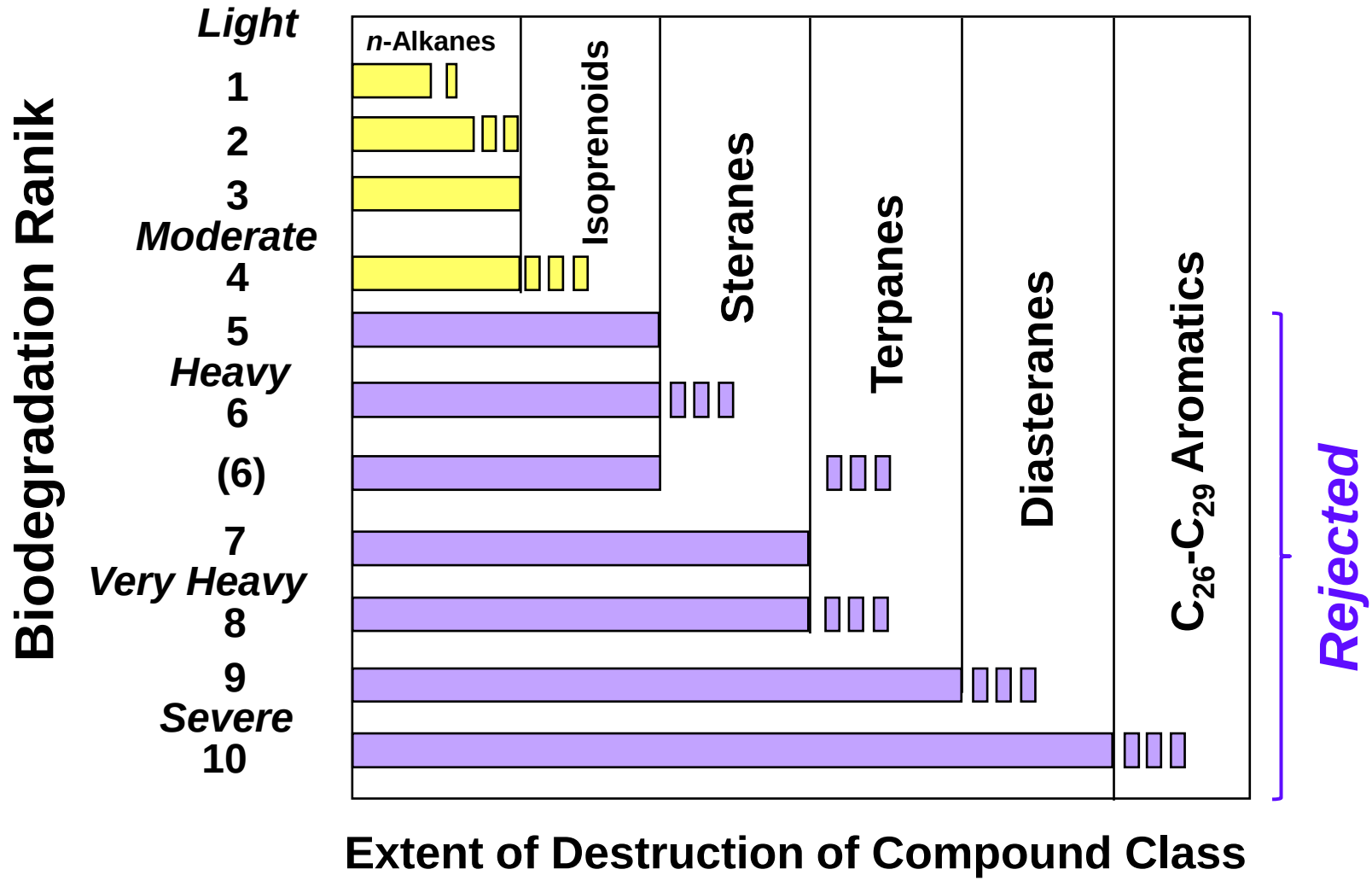
Modified from Wright (1991)

Oil Families: 24 *Source-Related* Biomarker & Isotope Ratios

Oil Sample	Biodegradation*	Terpanes																Steranes				Isotopes		
		C_{19}/C_{23}	C_{22}/C_{21}	C_{24}/C_{23}	C_{26}/C_{25}	C_{26}/Ts	Tet/C_{23}	$C_{27}T/C_{27}$	C_{28}/H	C_{29}/H	X/H	Ol/H	$C_{31}R/H$	Ga/31R	$C_{35}S/C_{34}S$	$C_{27}Ts/Tm$	$C_{29}Ts/Tm$	S/H	$\%C_{27}$	$\%C_{28}$	$\%C_{29}$	S1/S6	$\delta^{13}C_{sat}$	$\delta^{13}C_{aro}$	CV
ElS5S	0	0.0350	0.2470	0.7517	0.7903	1.8274	0.1190	0.0378	0.3835	0.5460	0.0192	0.1162	0.2847	0.1006	0.9857	0.4668	0.2008	1.7745	31.1369	41.6277	27.2354	0.1793	-25.02	-23.68	-0.92
LB6M	4	0.0332	0.1781	0.6544	1.1647	2.6412	0.1335	0.0590	0.4458	0.5961	0.0167	0.1319	0.2269	0.6705	0.8730	0.3510	0.1628	1.8849	29.7768	44.5270	25.6962	0.1514	-23.88	-22.94	-2.16
BvH7S	3	0.0263	0.2458	0.9474	0.8300	2.6974	0.1033	0.0329	0.2743	0.5091	0.0256	0.1405	0.2452	0.2843	0.9021	0.5314	0.2110	1.6759	30.0511	43.9406	26.0083	0.2100	-23.87	-23.16	-2.67
BvH26S	0	0.0202	0.2926	0.7979	0.8203	2.0286	0.1268	0.0560	0.3661	0.5678	0.0151	0.1439	0.2741	0.2774	0.9107	0.4159	0.1811	1.3432	31.9467	39.9842	28.0690	0.0125	-25.06	-23.67	-0.80
CvH27S	0	0.0237	0.2735	0.8494	0.9053	2.0887	0.1302	0.0499	0.1838	0.5275	0.0216	0.1478	0.2242	0.4121	0.6551	0.5258	0.1826	1.2655	30.6225	39.4825	29.8950	0.1942	-24.95	-23.64	-1.01
SwN28S	1	0.0202	0.2647	0.7878	0.8106	2.0852	0.1262	0.0559	0.3621	0.5702	0.0139	0.1472	0.2723	0.4088	0.9618	0.3826	0.1758	1.5505	30.6532	40.9345	28.4122	0.1608	-25.04	-23.73	-0.98
Wht42S	4	0.0555	0.2478	0.8727	1.0259	2.8864	0.0908	0.0815	0.2331	0.4251	0.0319	0.2837	0.1736	0.6051	0.6676	0.7019	0.2142	1.3942	32.0455	40.8963	27.0582	0.2966	-23.68	-23.05	-2.91
Wil78S	5	0.0169	0.2394	0.7959	0.7684	3.8077	0.0926	0.0514	0.4284	0.7302	0.0286	0.1976	0.3393	0.5113	0.9033	0.3726	0.1649	0.7196	32.7066	41.3216	25.9717	1.1362	-23.66	-22.96	-2.76
Wil79S	4	0.0166	0.2464	0.8045	0.7615	3.6745	0.0908	0.0573	0.3370	0.6352	0.0256	0.1622	0.2890	0.5523	0.9238	0.4197	0.1587	1.0619	33.0806	40.7143	26.2051	0.4414	-23.59	-22.91	-2.83

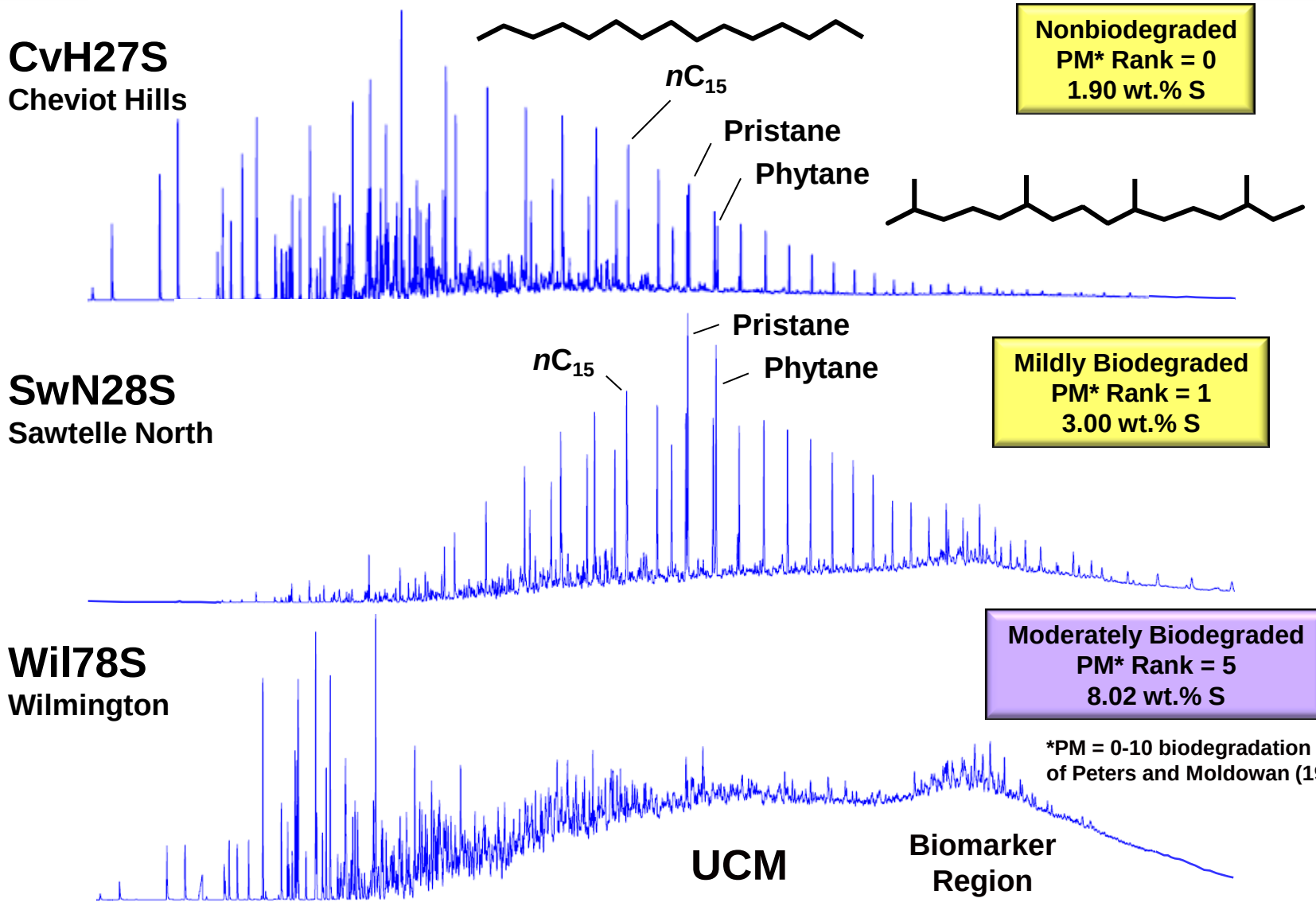
*0-10 biodegradation scale of Peters and Moldowan (1993)

Training Set: No Biodegradation of Steranes or Terpanes

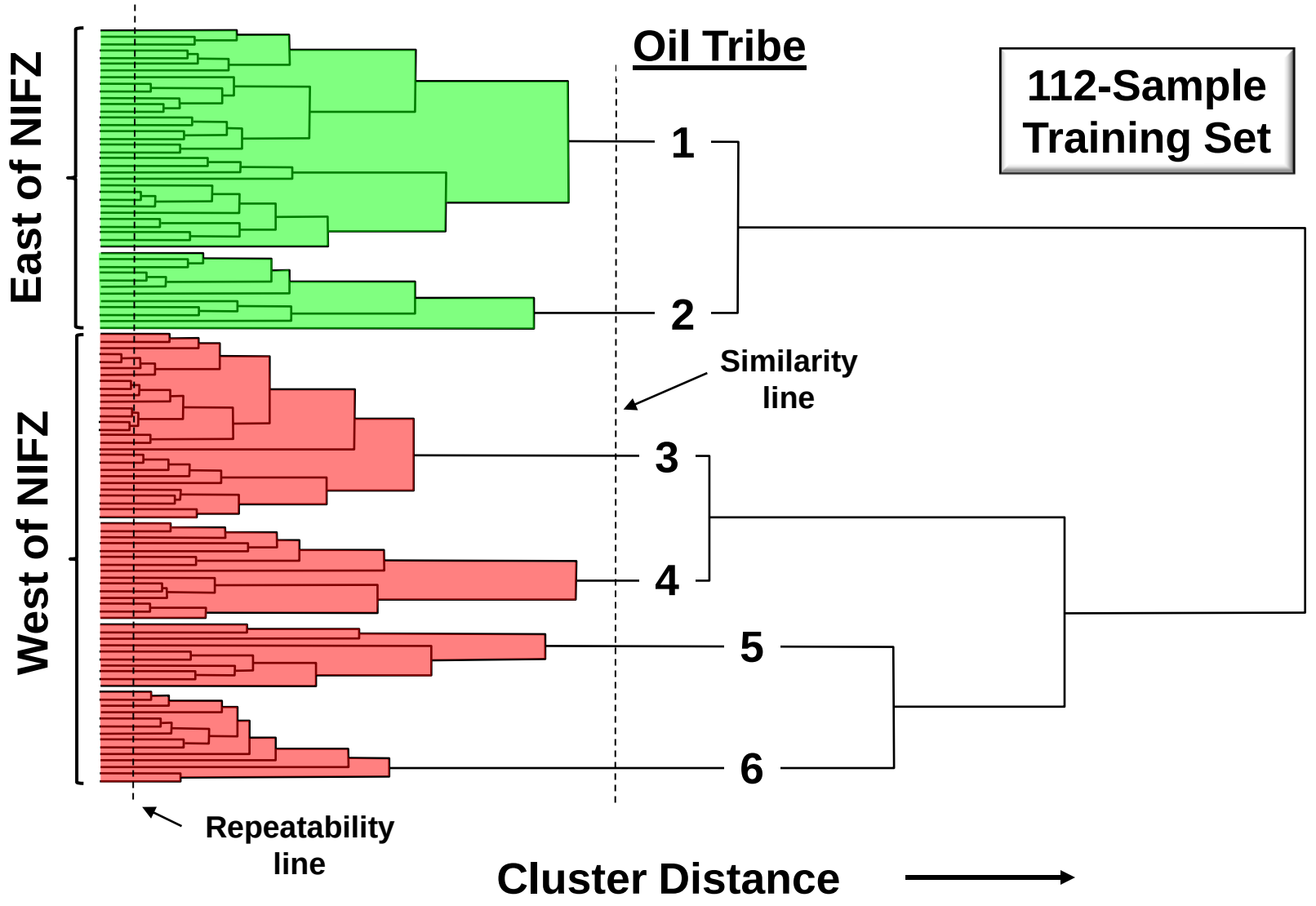


Peters and Moldowan (1993)

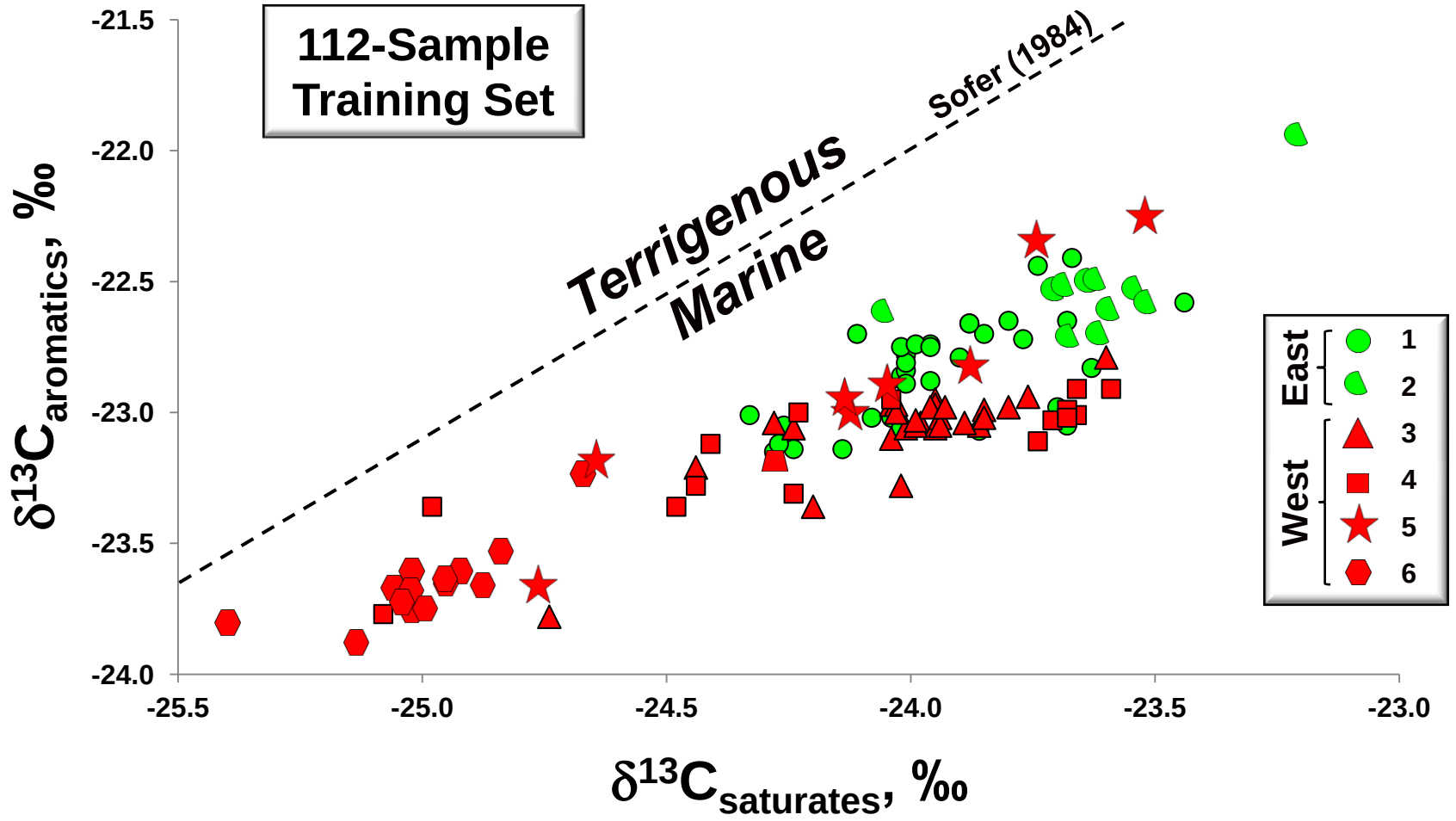
Oil Having Biodegradation Rank 5 or More was Rejected



6 Tribes: East/West of Newport-Inglewood Fault Zone (NIFZ)



All Samples Have a Miocene Isotopic Signature (^{13}C-Rich)

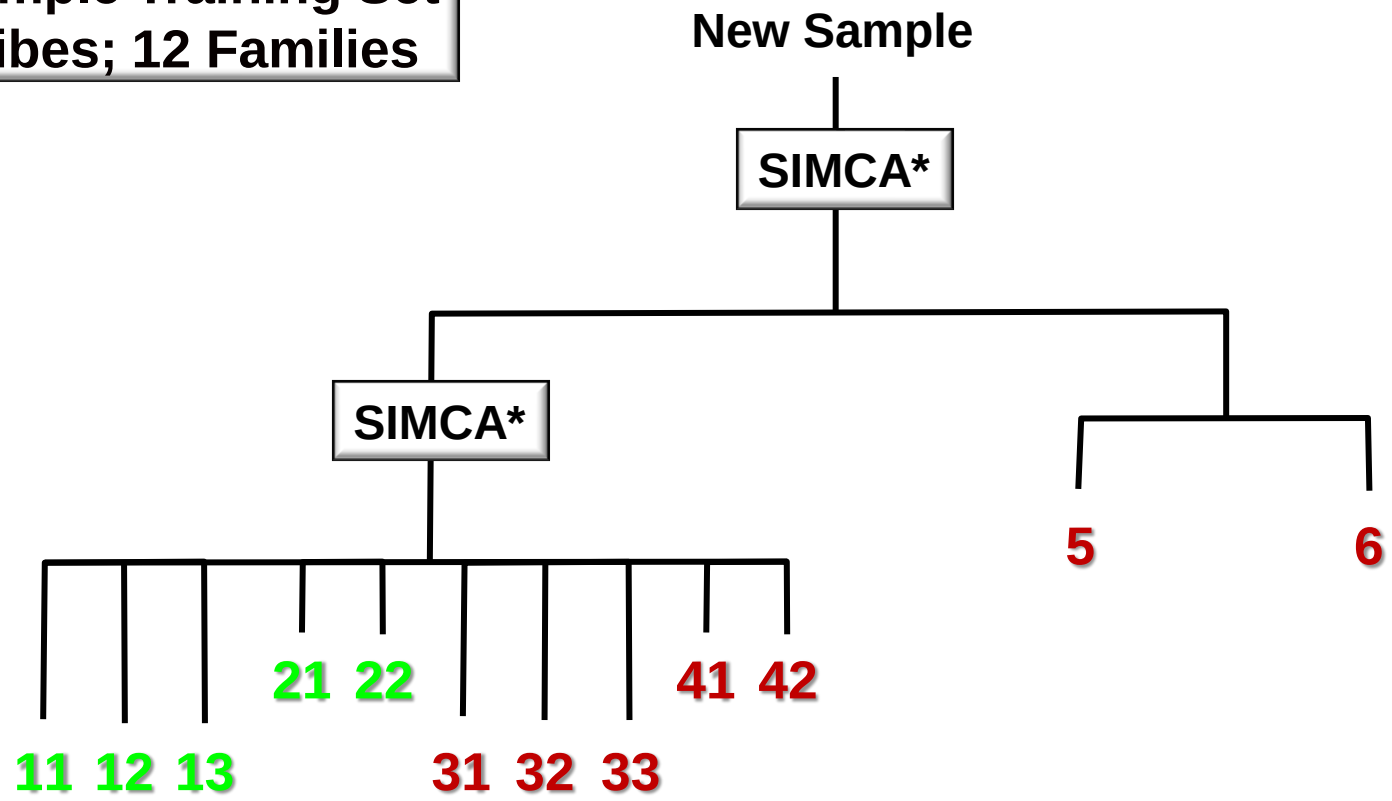


Tribes 1 and 2 are Enriched in Higher-Plant Biomarkers

Nerium oleander

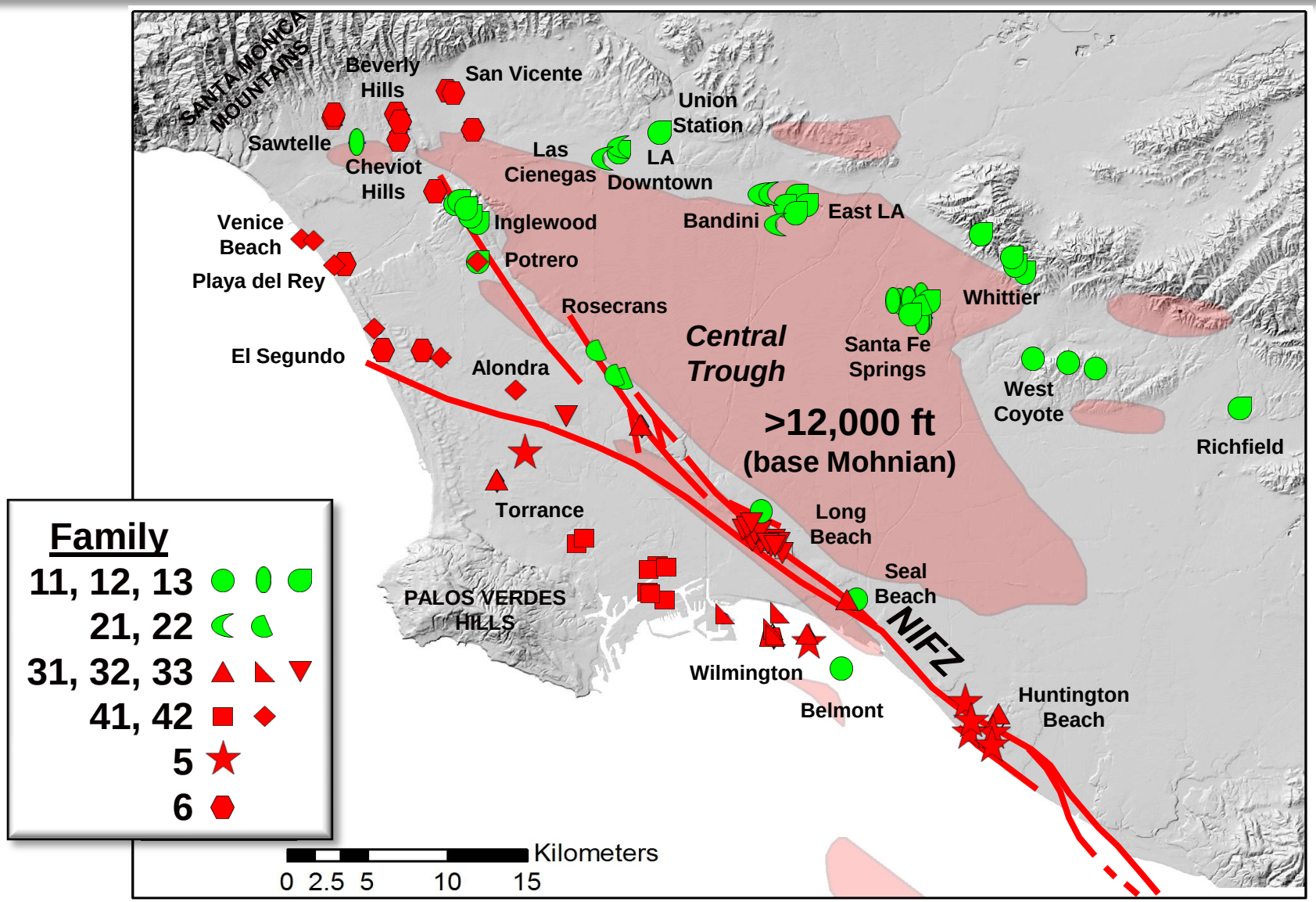
Chemometric Decision-Tree Classifies New Oil Samples

112-Sample Training Set
Six Tribes; 12 Families

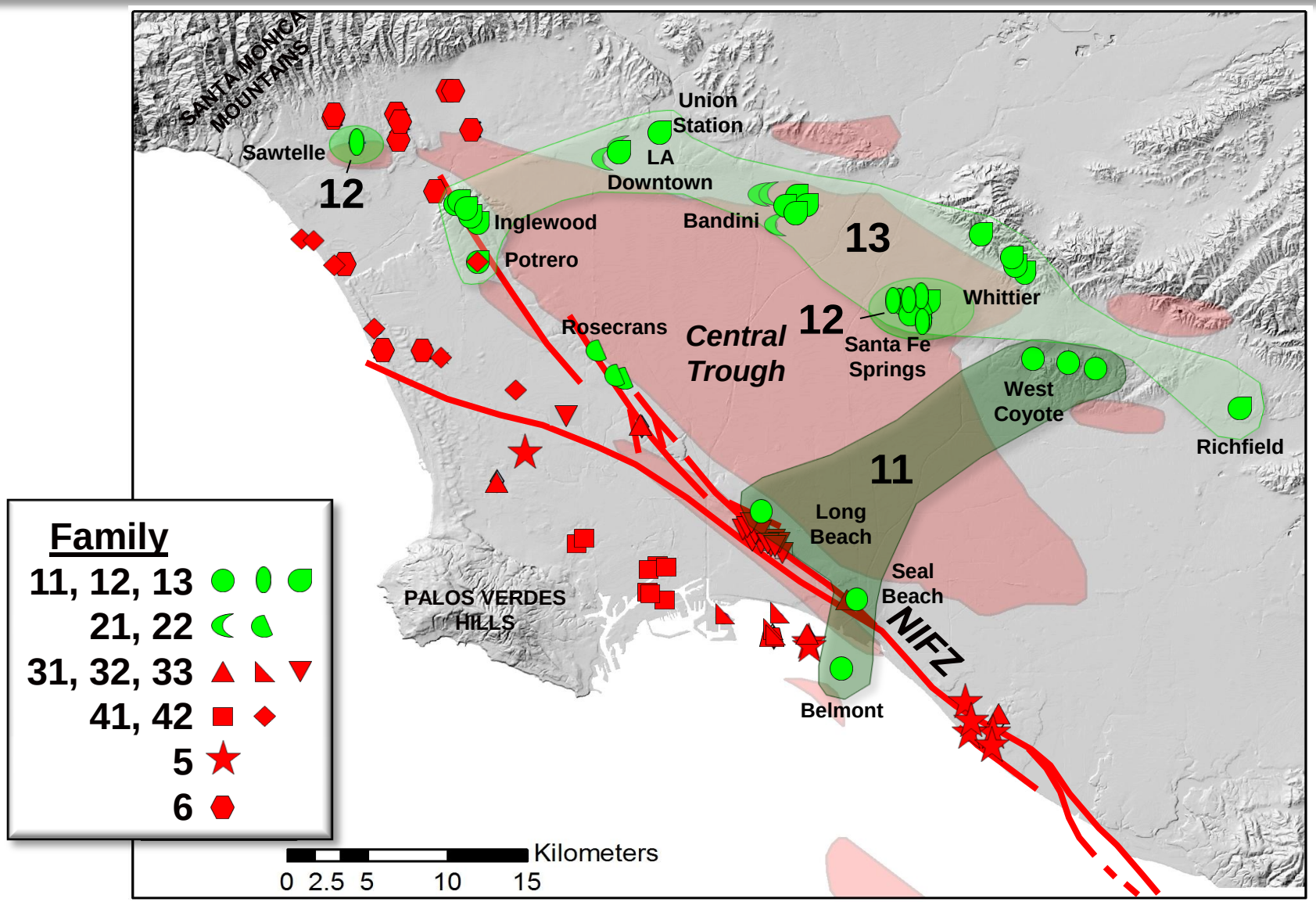


*Soft independent modeling of class analogy

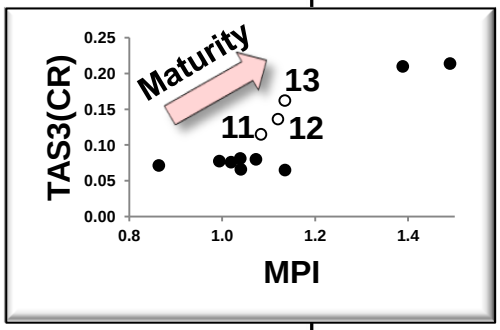
Families East/West of Newport-Inglewood Fault Zone (NIFZ)



Families in Tribe 1 Originated from Source Rock East of NIFZ

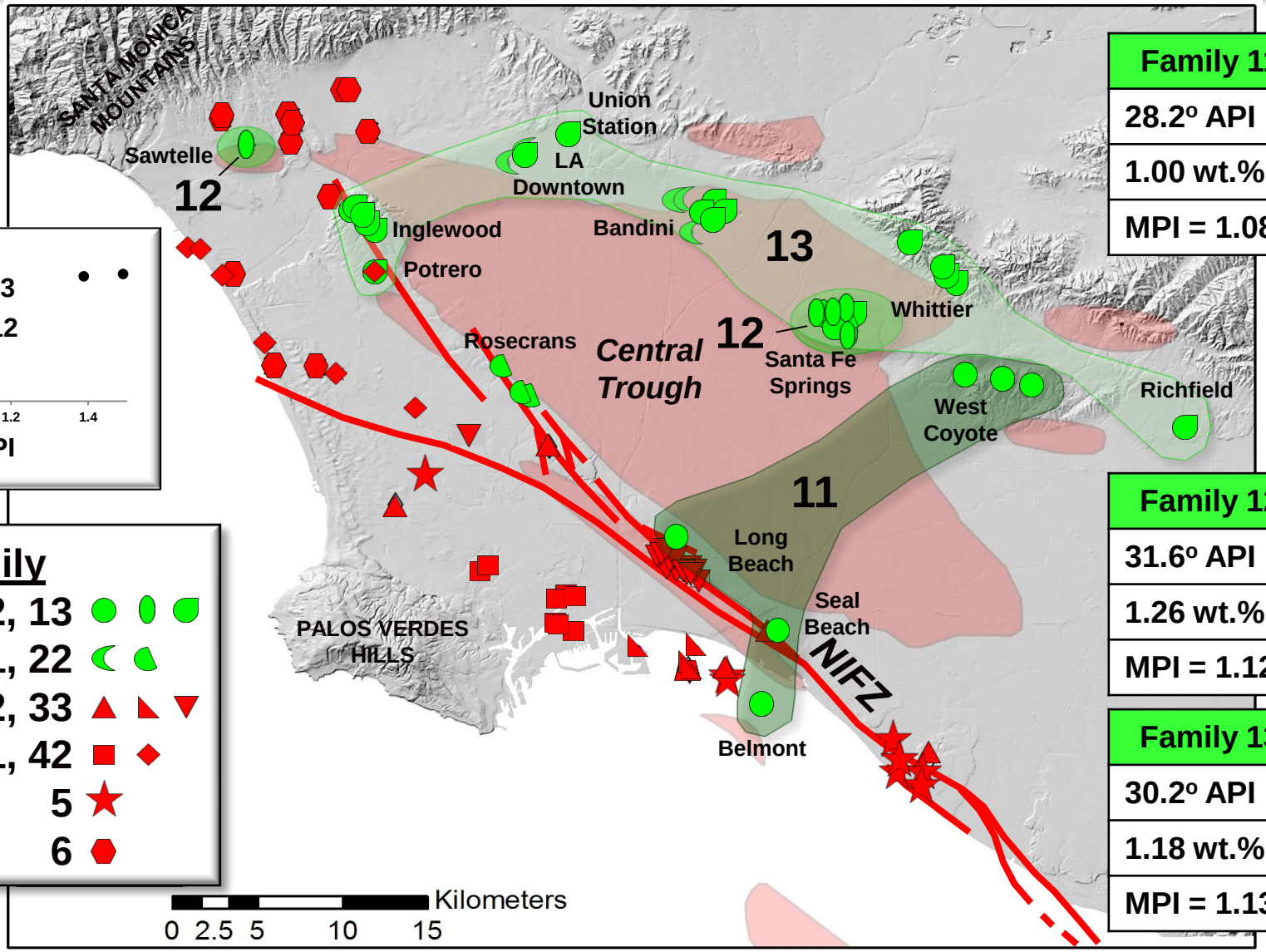


Families in Tribe 1 Originated from Source Rock East of NIFZ



Family

11, 12, 13	● ● ●
21, 22	◐ ◐
31, 32, 33	▲ ◣ ▼
41, 42	■ ◆
5	★
6	⬢

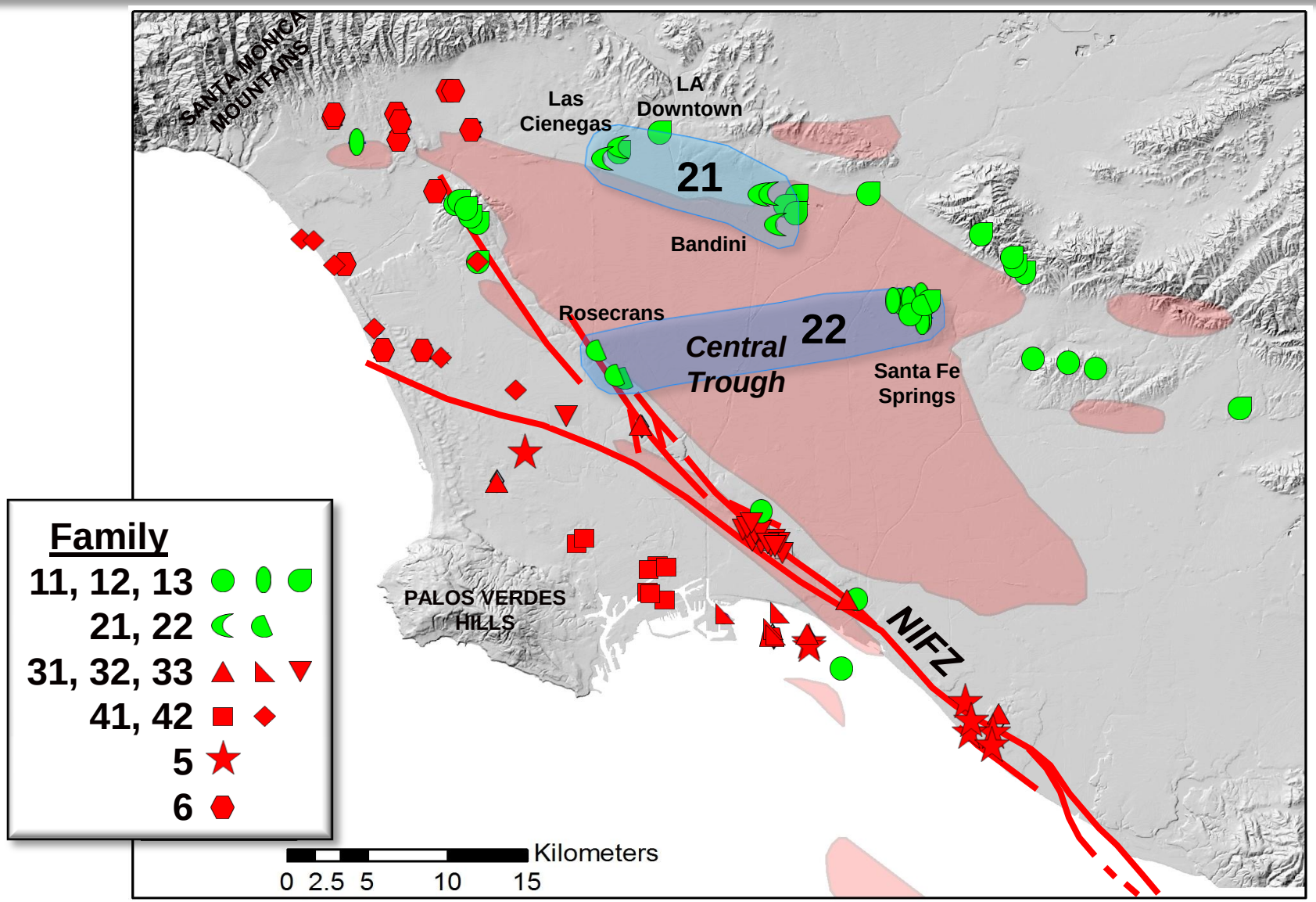


Family 11
28.2º API
1.00 wt.% S
MPI = 1.08

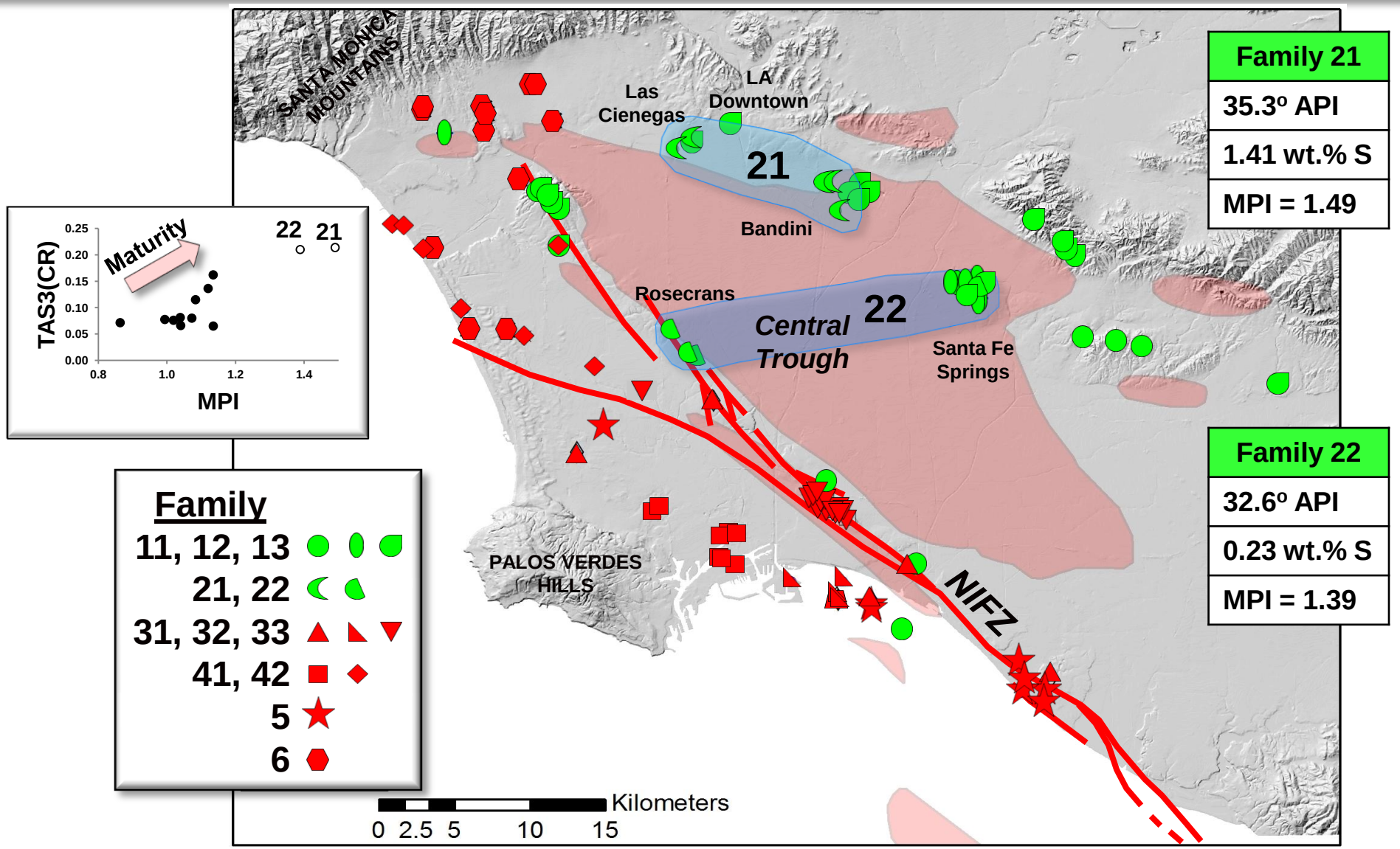
Family 12
31.6º API
1.26 wt.% S
MPI = 1.12

Family 13
30.2º API
1.18 wt.% S
MPI = 1.13

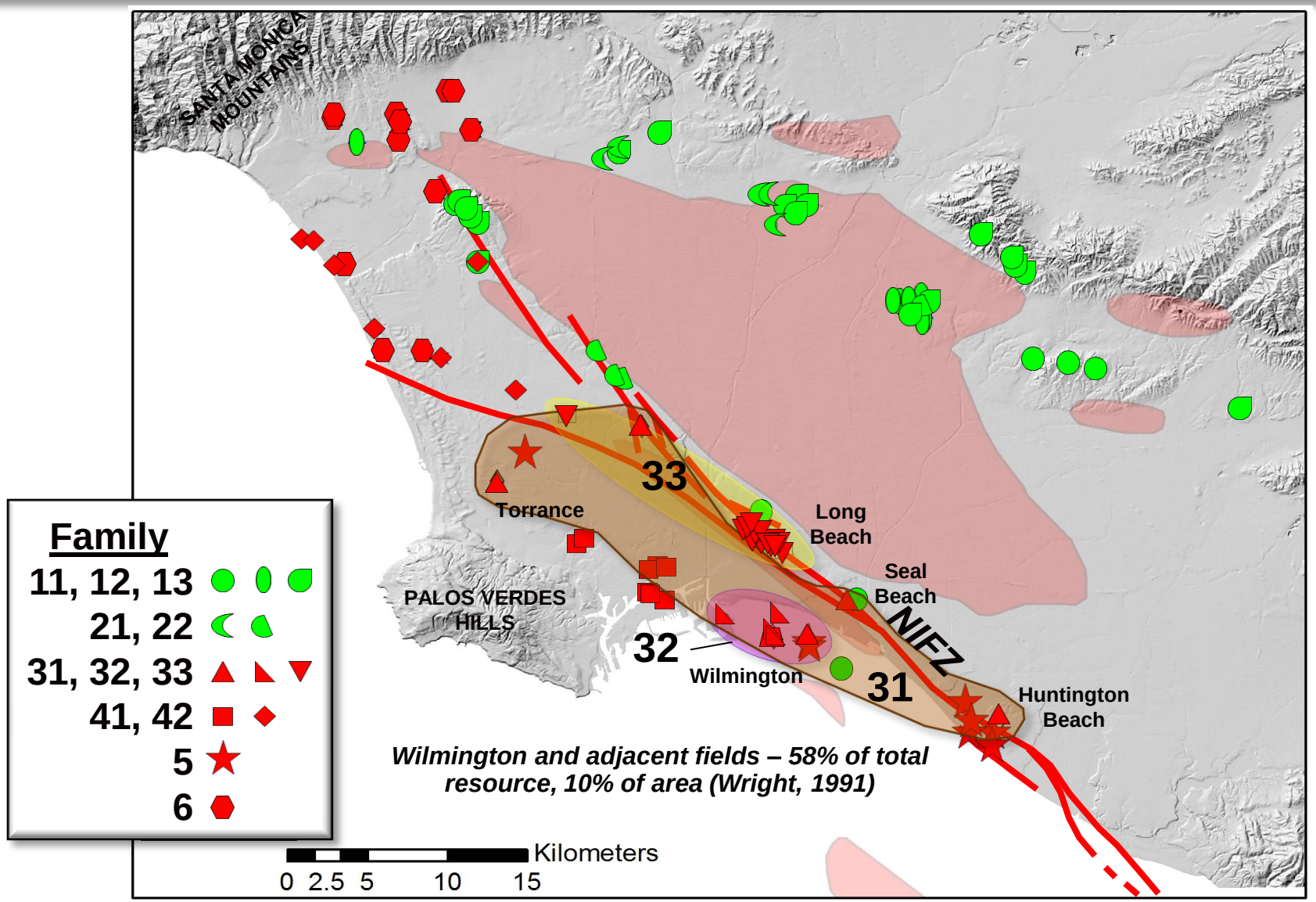
Families in Tribe 2 Originated from Source Rock East of NIFZ



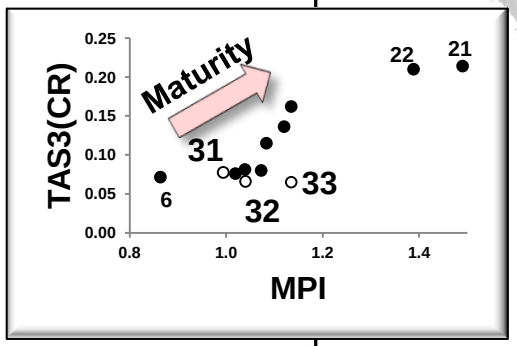
Families in Tribe 2 Originated from Source Rock East of NIFZ



Tribe 3 Families Originated from Source Rock West of NIFZ

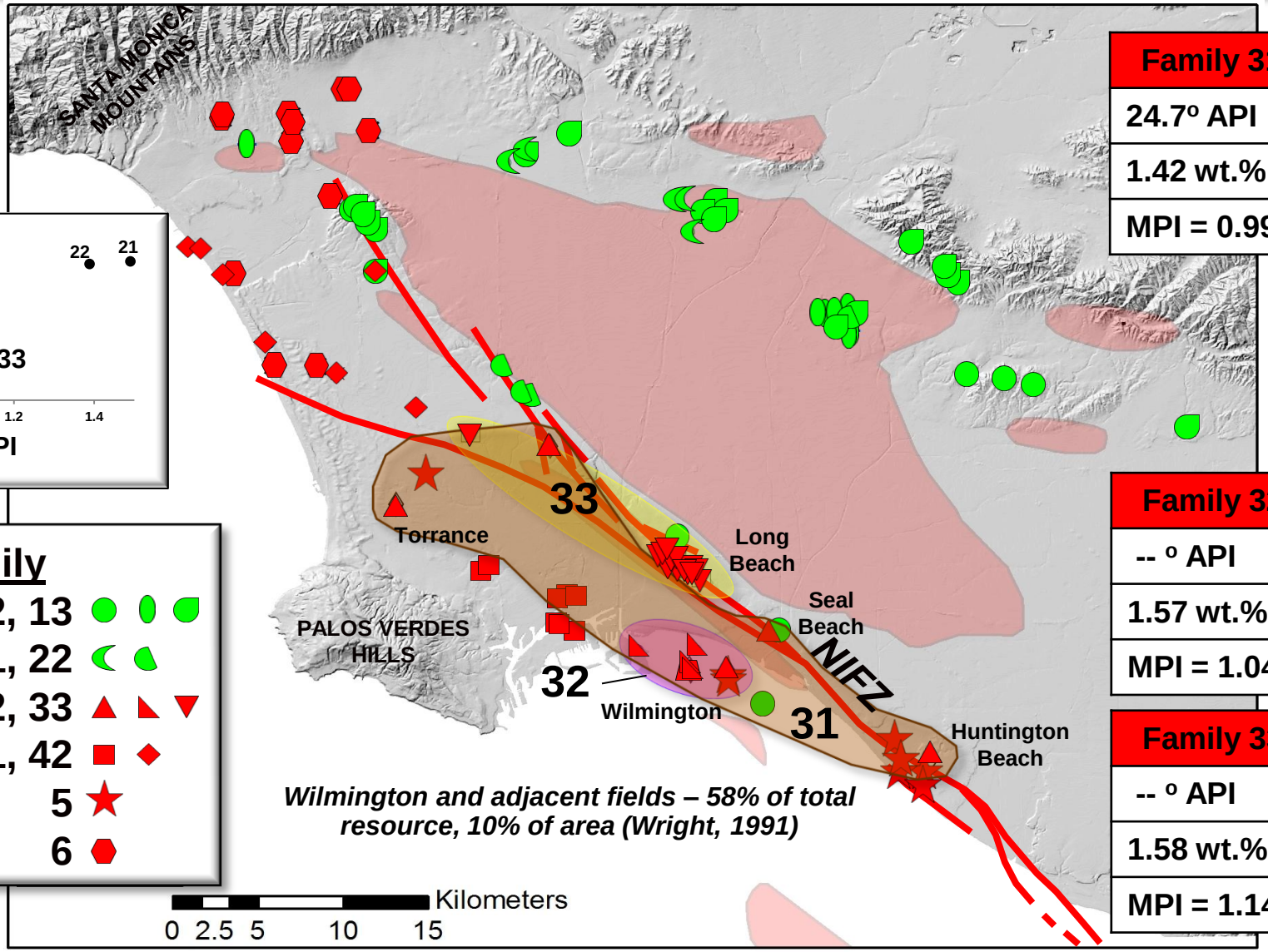


Tribe 3 Families Originated from Source Rock West of NIFZ



Family

11, 12, 13	● ◗ ◔
21, 22	◖ ◗
31, 32, 33	▲ ◣ ▼
41, 42	■ ◆
5	★
6	⬢



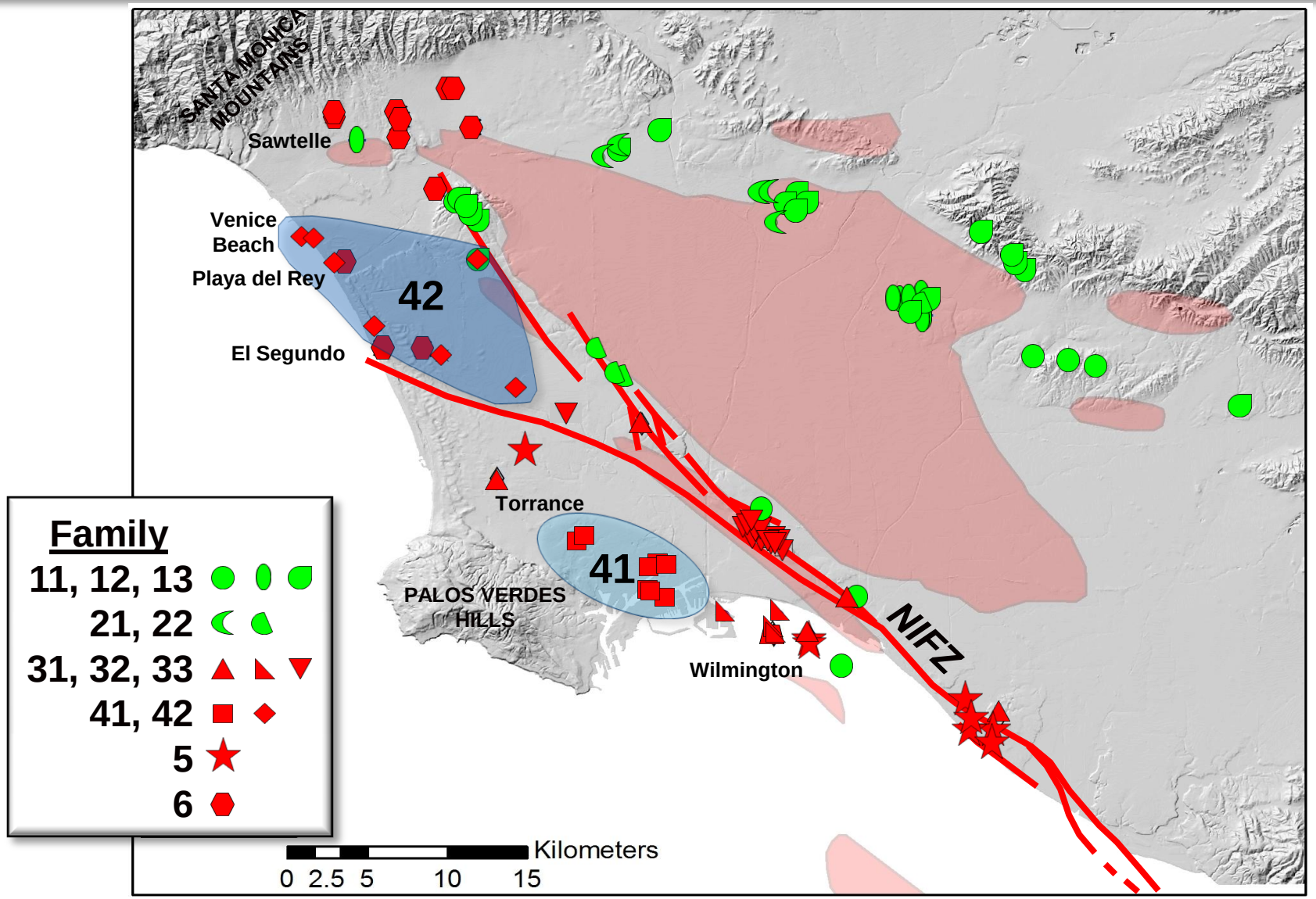
Wilmington and adjacent fields – 58% of total resource, 10% of area (Wright, 1991)

Family 31
24.7º API
1.42 wt.% S
MPI = 0.99

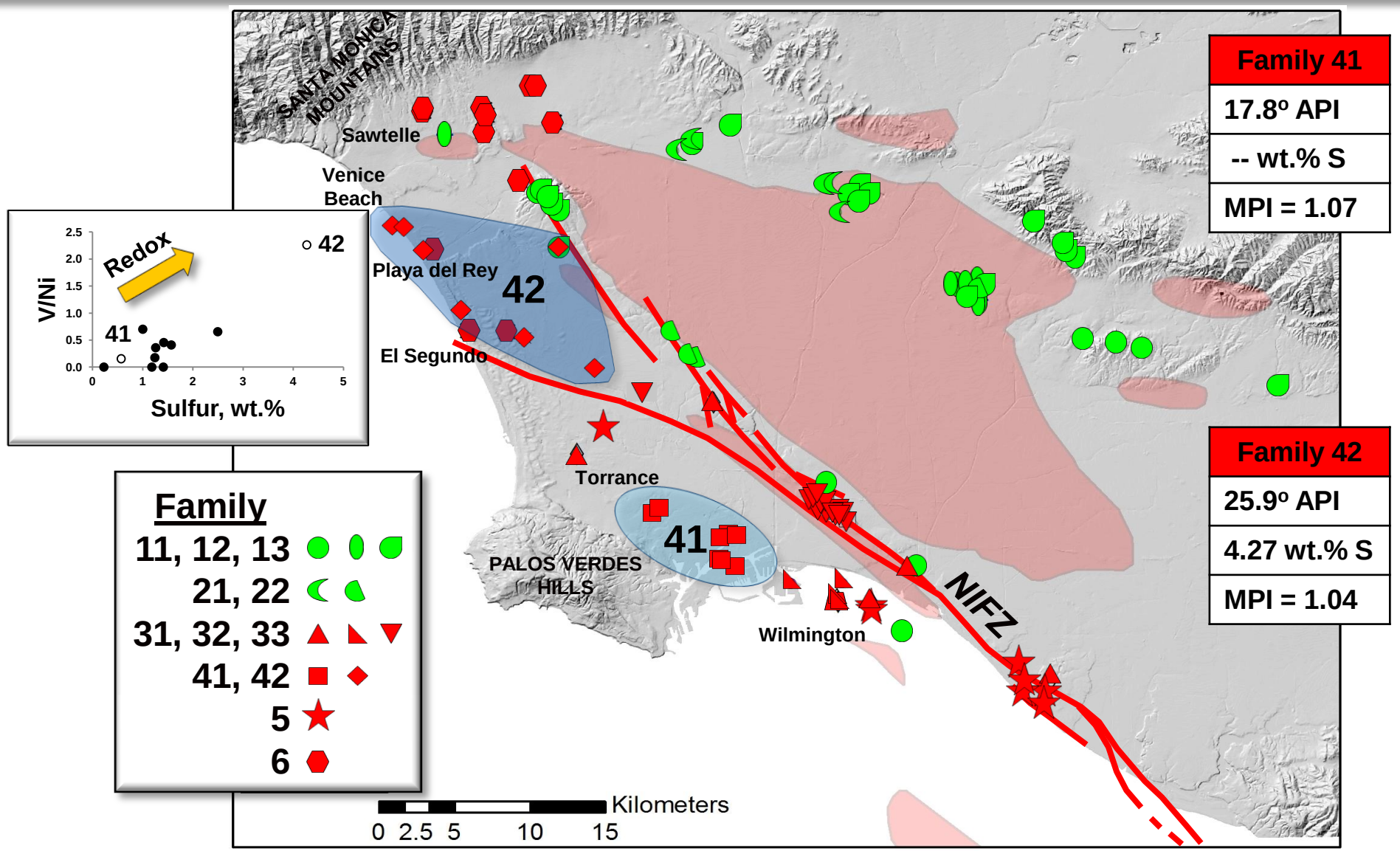
Family 32
-- º API
1.57 wt.% S
MPI = 1.04

Family 33
-- º API
1.58 wt.% S
MPI = 1.14

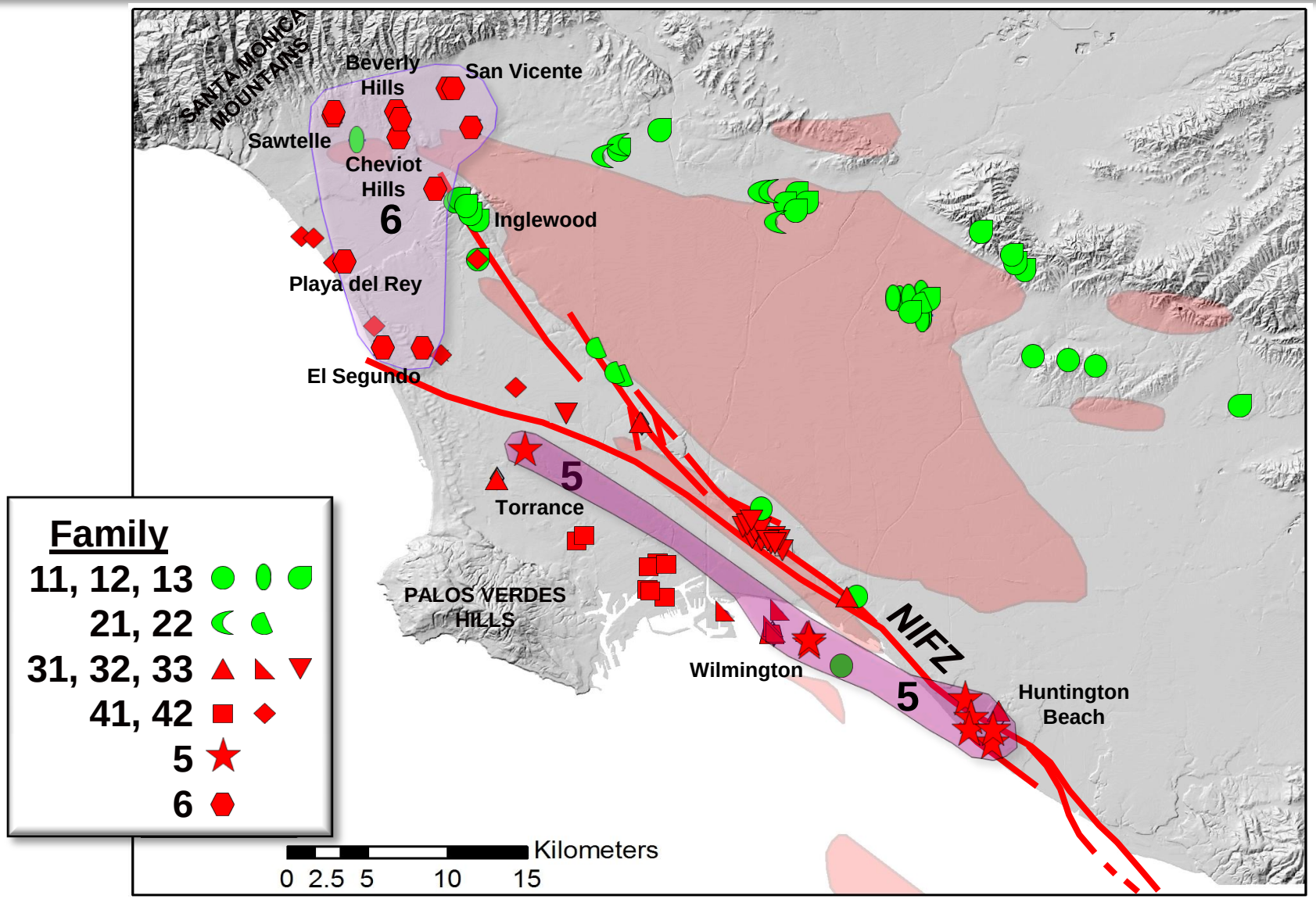
Tribe 4 Families Originated from Source Rock West of NIFZ



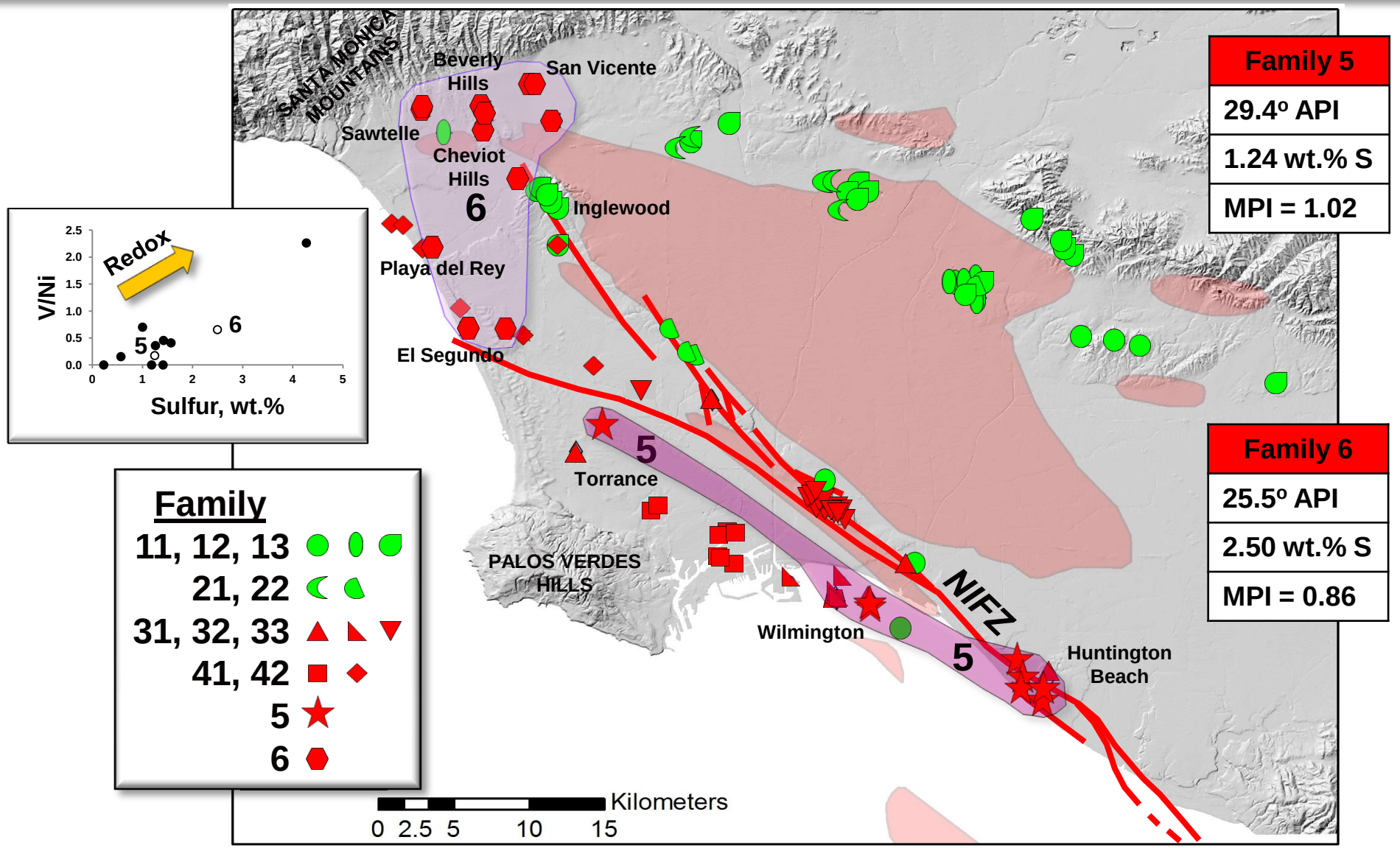
Tribe 4 Families Originated from Source Rock West of NIFZ



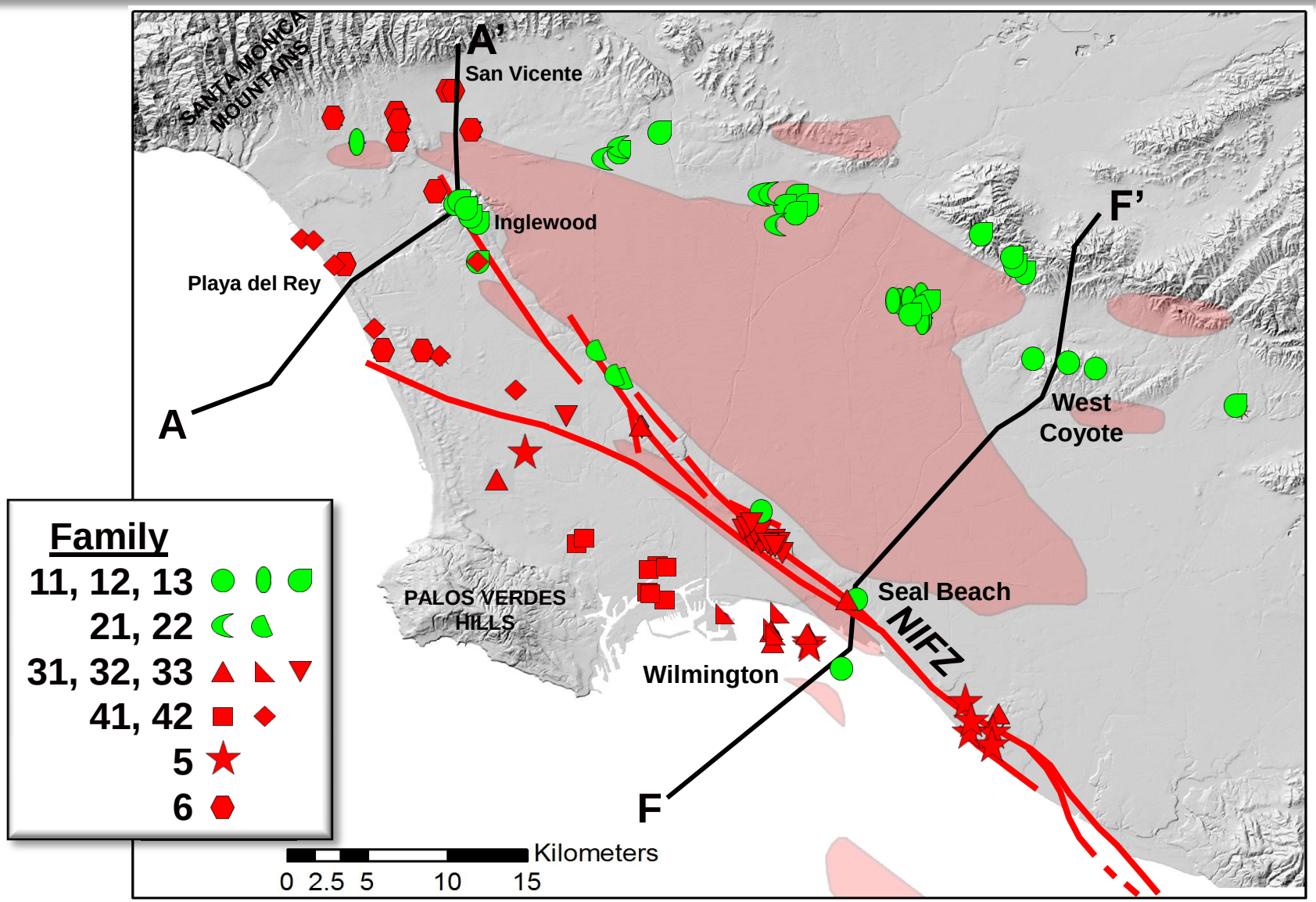
Tribes 5 and 6 Originated from Source Rocks West of NIFZ



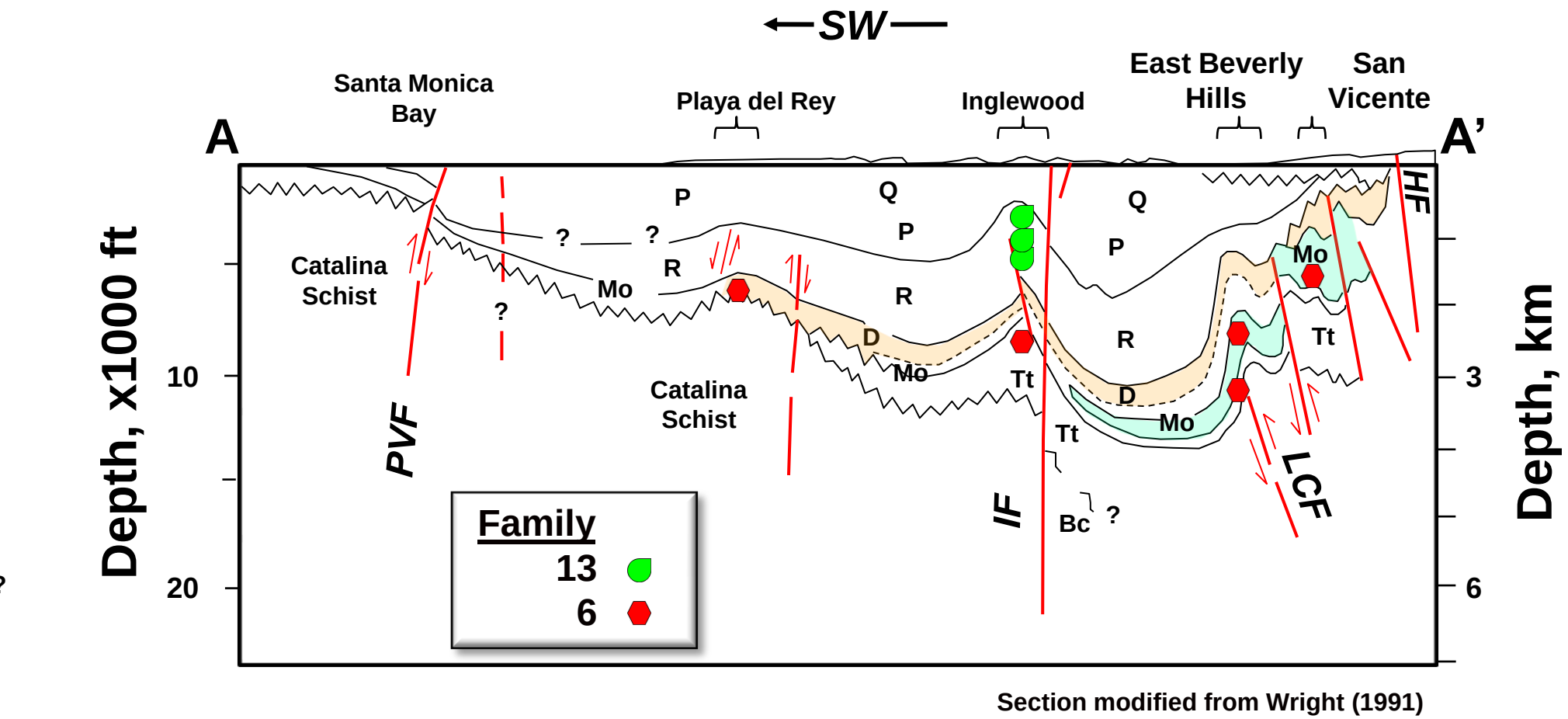
Tribes 5 and 6 Originated from Source Rocks West of NIFZ



Cross Sections Reveal Stratigraphy of Some Oil Families

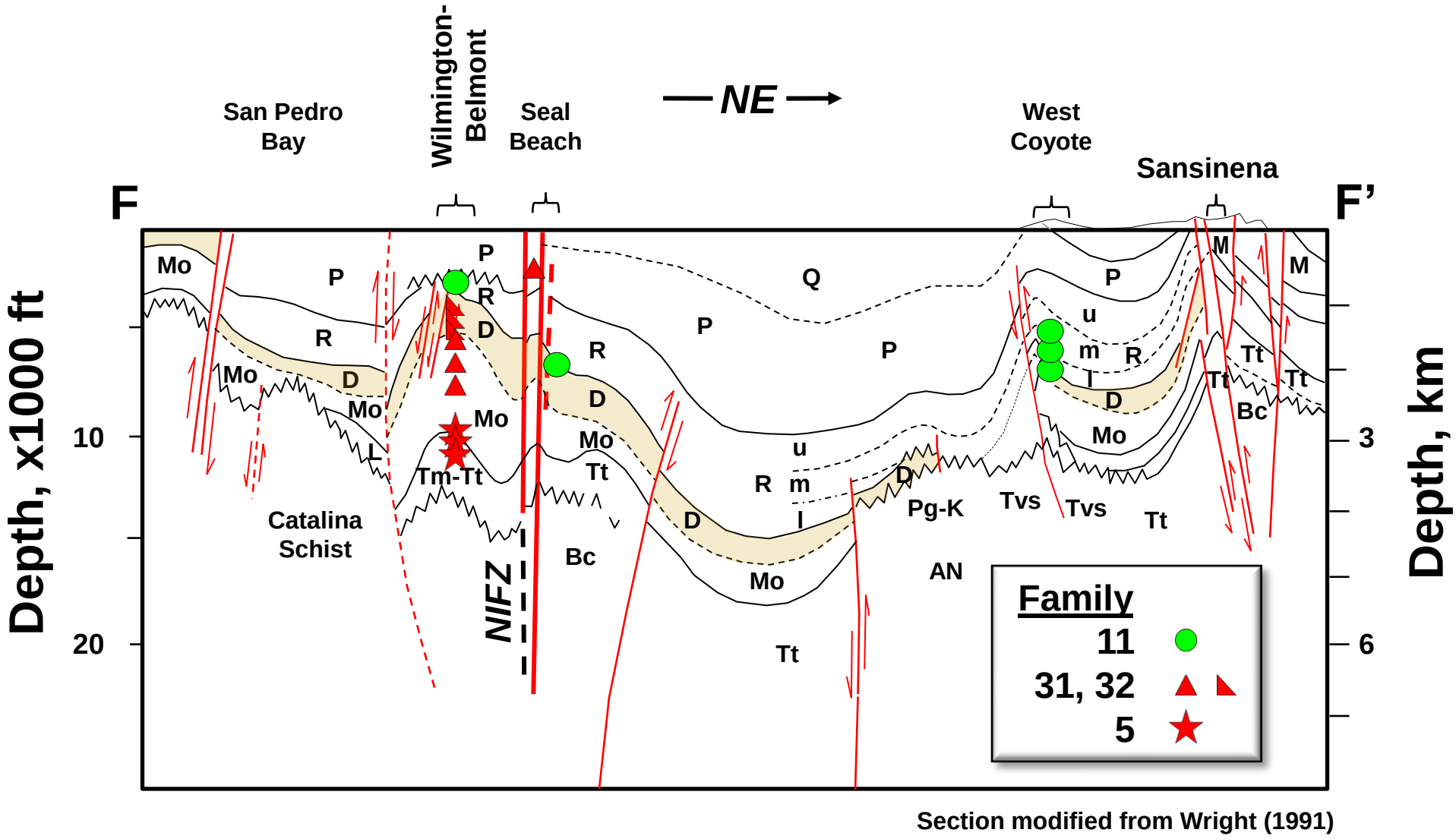


A-A' Section Reveals Stratigraphy of Tribe 6 and Family 13



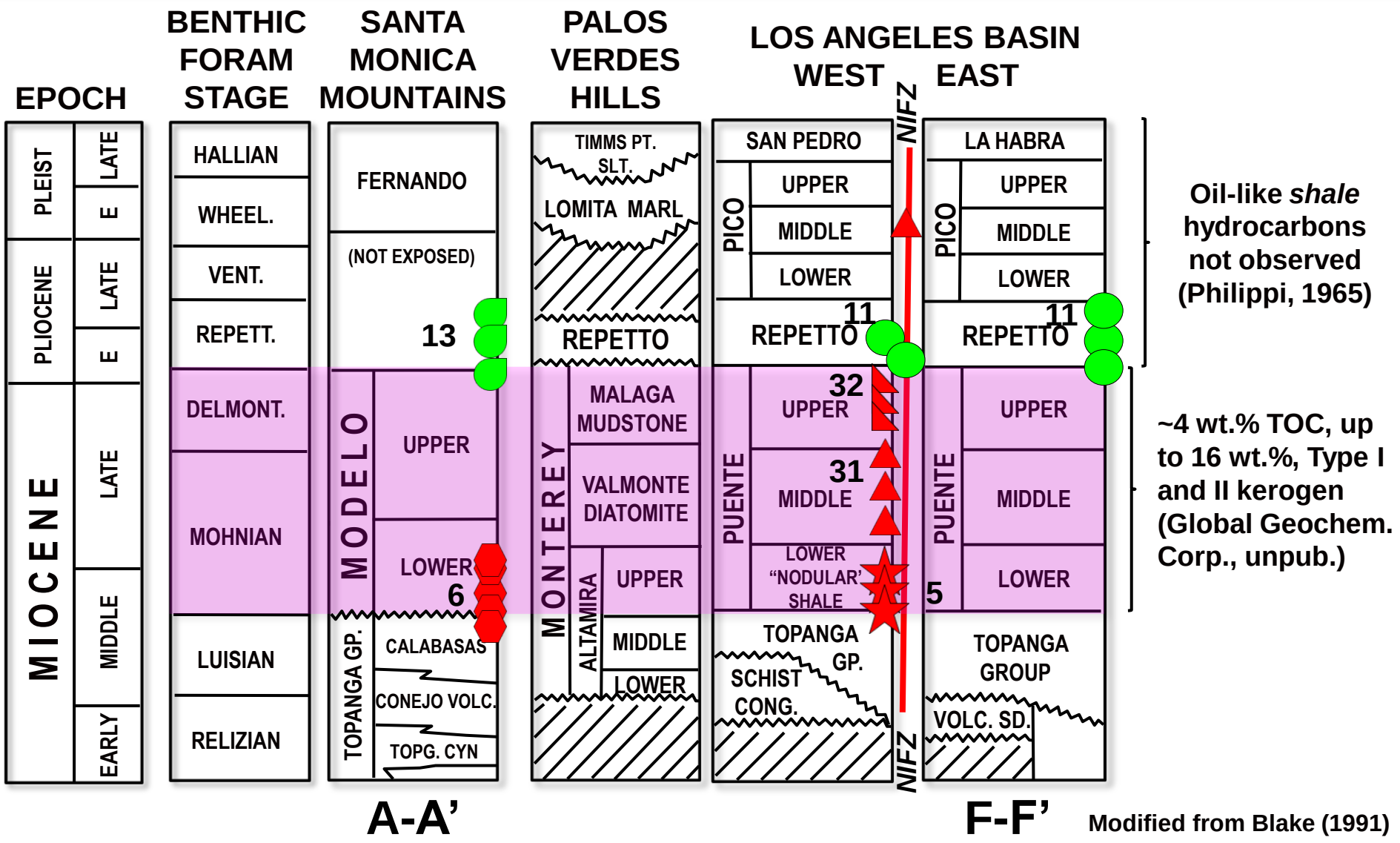
Section modified from Wright (1991)

F-F' Section Reveals Stratigraphy of Families 5, 11, 31, 32



Section modified from Wright (1991)

Stratigraphy Suggests Source Rocks for Oil Families



Oil-like *shale* hydrocarbons not observed (Philippi, 1965)

~4 wt.% TOC, up to 16 wt.%, Type I and II kerogen (Global Geochem. Corp., unpub.)

Modified from Blake (1991)

Source Rock Can be Inferred from Stratigraphy-Biomarkers

- **Suboxic Upper Miocene (Delmontian) shale with significant angiosperm input generated Tribes 1-2 at moderate-high maturity in the Central Trough east of NIFZ.**
- **Anoxic Upper Miocene (M.-U. Puente) marl source rock generated Tribe 3 west of NIFZ.**
- **Anoxic Mohnian(?) marl generated Tribe 4 west of NIFZ.**
- **Anoxic M.-U. Miocene (L. Puente “nodular shale”) marl with significant terrigenous plant input generated Tribe 5 southwest of NIFZ.**
- **Anoxic M.-U. Miocene (L. Modelo “nodular shale”) marl with significant terrigenous plant input generated Tribe 6 at low maturity northwest of NIFZ.**

Conclusions: Los Angeles Basin Geochemistry

- **At least six genetically distinct Miocene petroleum systems (12 families) occur in different parts of the basin.**
- **The Newport-Inglewood fault separates tribes 1-2 (families 11, 12, 13, 21, 22) to the east from tribes 3-6 (families 31-33, 41-42, 5, 6) to the west.**
- **Biomarker and isotope ratios as well as distinct stratigraphic occurrence help to identify likely source rock for each family.**
- ***Thermally mature source rock samples for direct oil-source rock correlation and 3D petroleum system modeling with partner(s) would useful to delineate pods of active source rock, migration paths, and undiscovered accumulations.***

Thanks for Your Attention!

References

- Blake, G.H., 1991, Review of the Neogene biostratigraphy and stratigraphy of the Los Angeles basin and implications for basin evolution: AAPG Memoir 52, 135-184.
- Jeffrey, A.W.A. et al., 1991, Geochemistry of Los Angeles basin oil and gas systems: AAPG Memoir 52, 197-219.
- McCulloh, T.H. et al., 1994, How oil composition relates to kerogen facies in the world's most petroliferous basin: AAPG Search and Discovery Article #90986, AAPG Annual Convention, Denver, CO, June 12-15, 1994.
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