Petroleum Systems and Mixed Oil in the Barents Sea and Northern Timan-Pechora Basin, Russia*

Meng He[1], Kenneth E. Peters[2], J. Michael Moldowan[3], and Alla Rovenskaya[4]

Search and Discovery Article #10357 (2011)
Posted September 26, 2011

*Adapted from oral presentation at 3P-Polar Petroleum Potential Conference & Exhibition, Halifax, Nova Scotia, Canada, August 30-September 2, 2011, hosted and organized by AAPG and Allworld Exhibitions.

[1]Geological & Environmental Sciences, Stanford University, Stanford, CA (KPeters2@slb.com)
[2]Schlumberger, Mill Valley, CA
[3]Biomarker Technology, Sebastopol, CA
[4]Foundation for East-West Cooperation, Moscow, Russian Federation

Abstract

Biomarkers and diamondoids were used to identify petroleum systems and infer source rocks for 34 oil samples from the Barents Sea and northern Timan-Pechora Basin. Chemometric analysis indicates five oil families from Triassic, Devonian (carbonate), Devonian (marl), Lower-Middle Jurassic, and Upper Jurassic source rocks. Based on the method of Dahl et al. (1999), 14 samples are mixtures of mature oil and highly mature condensate from deep, previously undetected source rock. Compound-specific isotope analyses of biomarkers and diamondoids show that highly mature Devonian source rock contributes to most of the mixed oil samples.

The Triassic oil family occurs in Triassic and Permian reservoirs in the northern Timan-Pechora Basin and the southern Barents Sea. The oils have high extended tricyclic terpane ratios (ETR), consistent with Triassic source rock. The Devonian carbonate oil family occurs in Permian and Devonian reservoirs in the northern Timan-Pechora Basin and Pechora Sea. The oils show high C_{29}/C_{30} hopane, pristane/phytane (Pr/Ph) <1, elevated C_{34}-homohopanes and C_{29} steranes, and low dinosteroids. The oils from Devonian marl source rock occur in Devonian reservoirs in the northern Timan-Pechora Basin. They are similar to the carbonate family, but have Pr/Ph >1 and lack elevated C_{34} homohopanes.

The two Jurassic oil families have high bicadinanes and triaromatic dinosteroids, consistent with Jurassic source rock having terrigenous input. The Lower-Middle Jurassic oils occur in Lower-Middle Jurassic reservoirs in the Shtokmanovskoye Field and on Spitsbergen Island. These oils have Pr/Ph >3, high $C_{19}/(C_{19}+C_{23})$, low C_{22}/C_{21}, and high C_{24}/C_{23} tricyclic terpane ratios, and elevated C_{29} steranes indicating paralic marine shale source rock with higher plant-input, similar to oil generated from the Tyumen Formation

in West Siberia (Peters et al., 2007). The Upper Jurassic oil family occurs in Triassic and Permian reservoirs on Kolguyev Island and the Pechora Sea. The oils show geochemical properties like those previously ascribed to the Bazhenov Formation in West Siberia (Peters et al., 2007).

References

Dahl, J.E., J.M. Moldowan, K.E. Peters, G.E. Claypool, M.A. Rooney, G.E. Michael, M.R. Mello, and M.L. Kohnen, 1999, Diamondoid hydrocarbons as indicators of natural oil cracking: Nature, v. 399, p. 54-57.

Peters, K.E., L.S. Ramos, J.E. Zumberge, Z.C. Valin, C.R. Scotese, and D.L. Gautier, 2007, Circum-Arctic petroleum systems identified using decision-tree chemometrics: AAPG Bulletin, v. 91, p. 877-913.

3P Arctic Conference & Exhibition

Halifax, Nova Scotia; 30 August-2 September, 2011

Arctic Petroleum Systems; 8:55 am Thursday

Petroleum Systems and Mixed Oil in the Barents Sea and Northern Timan-Pechora Basin, Russia

Meng He[1], Ken Peters[1,2], Michael Moldowan[1,3], and Alla Rovenskaya[4]

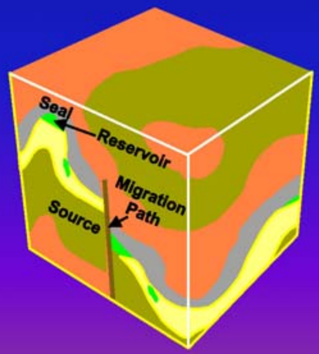
[1]Stanford University, Stanford, CA 94305; hmenglxq@stanford.edu
[2]Schlumberger, Mill Valley, CA 94941; kpeters2@slb.com
[3]Biomarker Technology, Sebastopol, CA 95472; moldowan@stanford.edu
[4]Foundation for East-West Cooperation, Moscow, Russia; tnemchenko@mail.ru

Study Area Includes the Barents Sea and Onshore/Offshore Timan-Pechora Basin

Notes by Presenter: Map of the Timan-Pechora Basin shows identified oil families.

Purpose of the Presentation

- Analyze 34 crude oils to identify oil families using principal components analysis (PCA) of 22 age- and source-related biomarker and isotope ratios
- Infer distributions of the effective source rocks
- Use diamondoids and compound-specific isotope analysis to identify mixed oils having both oil-window and highly cracked components



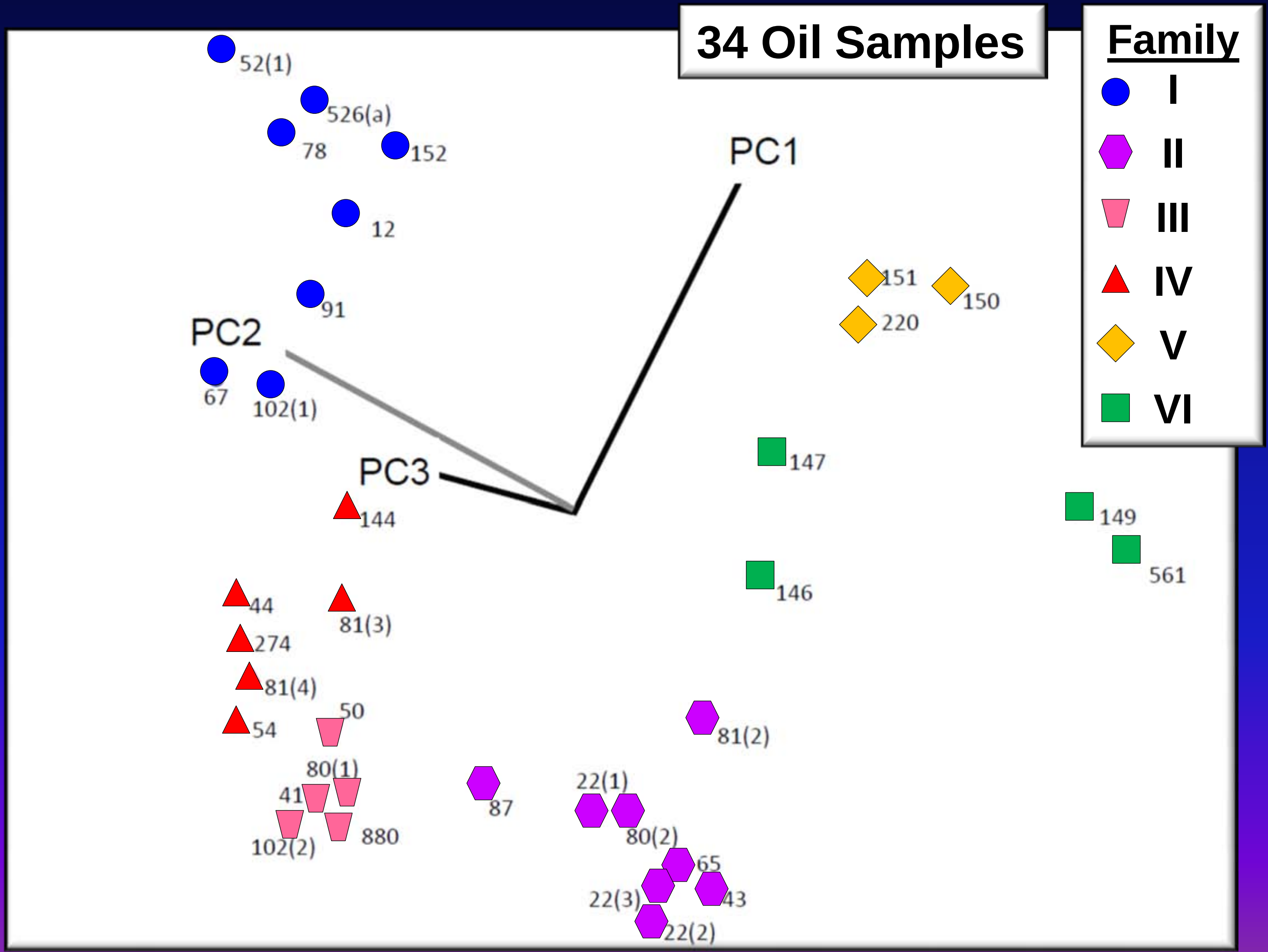
Notes by Presenter:
Four proposed source rocks (Dore, 1995):

- Jurassic
- Triassic

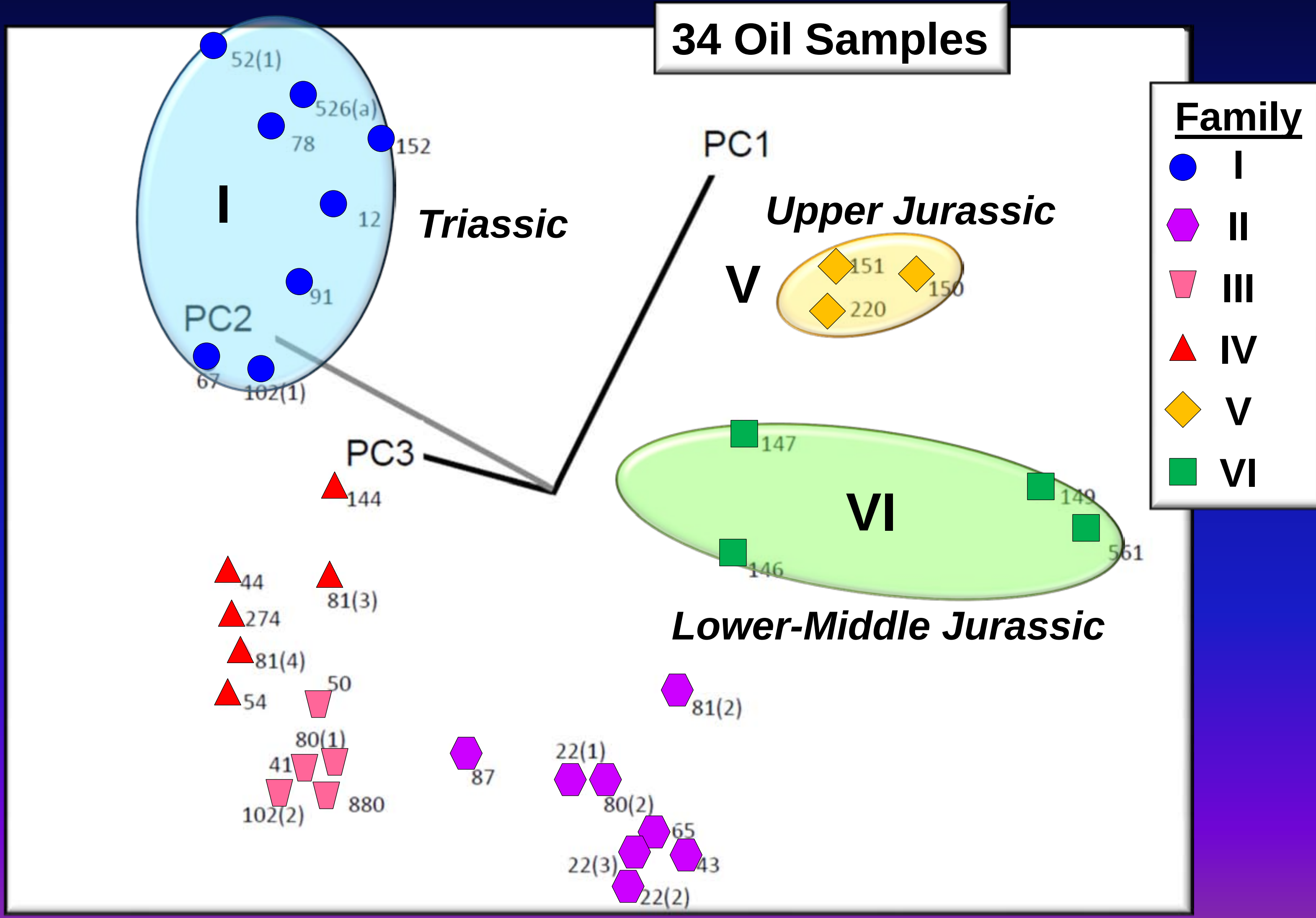
  (Middle Tr. in Northern Barents Sea; Lower Tr. in Southern Barents Sea)

3) Lower Permian (insufficient TOC 0.75-1.0%; Ulmishek, 1982)
4) Domanik (Upper Devonian)

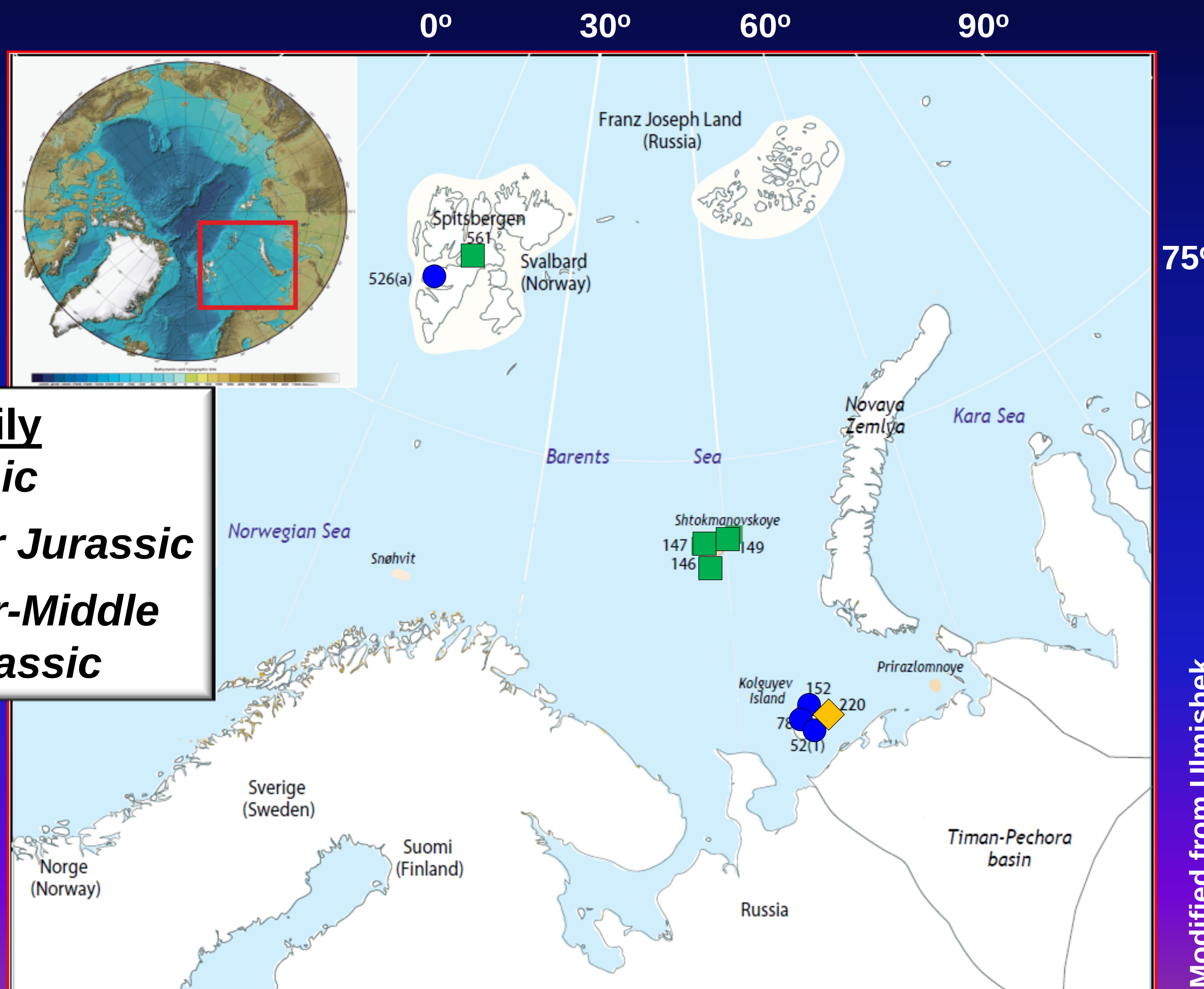
PCA of 22 Source-Related Biomarker and Isotope Ratios Identifies Six Oil Families



Mesozoic Oil Families I, V, and VI Occur in the Barents Sea



Mesozoic Families I (*Triassic*), V (*U. Jurassic*), and VI (*L.-M. Jurassic*) Occur in the Barents Sea



Family

- I) *Triassic*
- V) *Upper Jurassic*
- VI) *Lower-Middle Jurassic*

Modified from Ulmishek (1982) and Lindquist (1999)

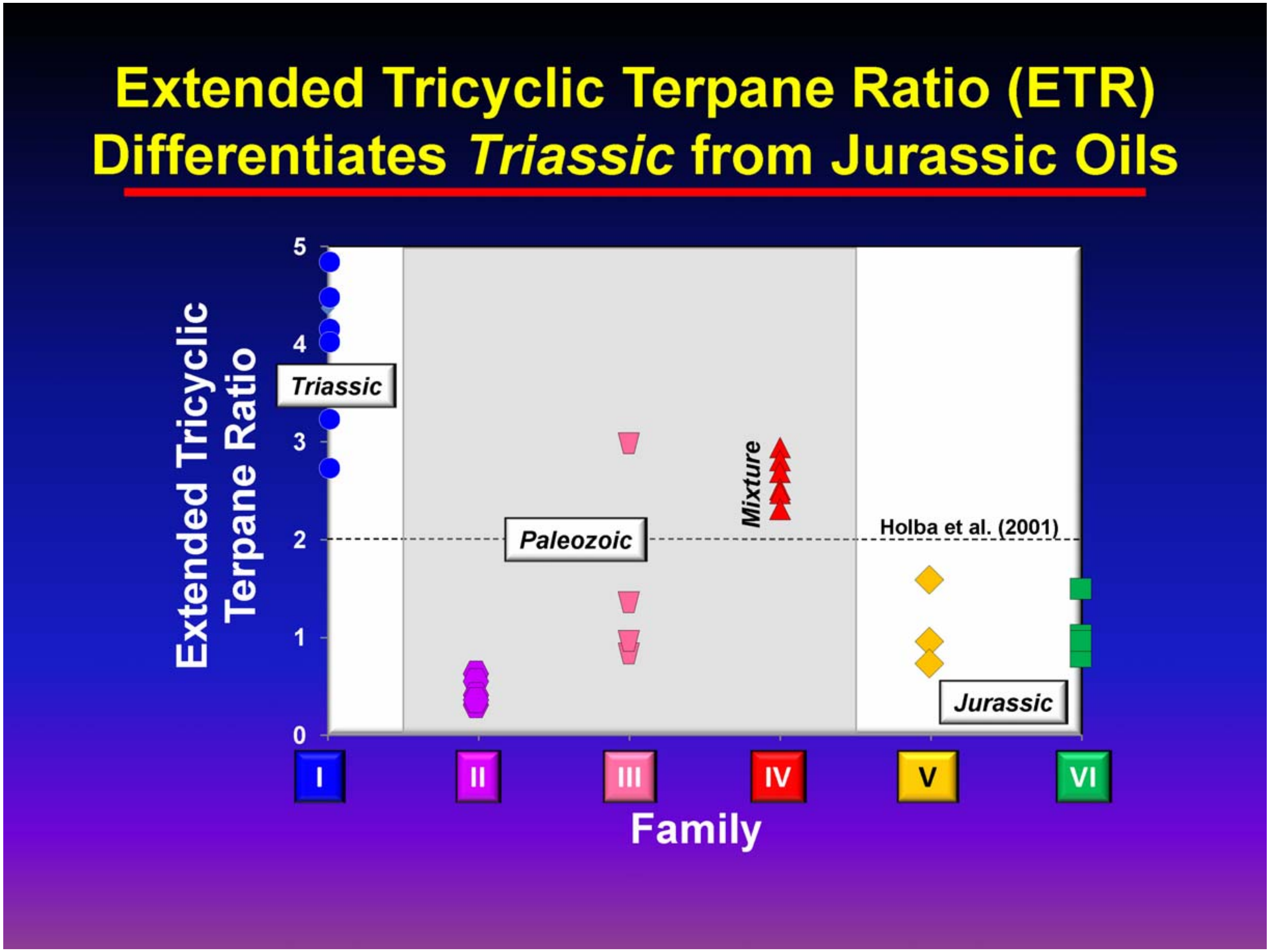
Source- and Age-Related Biomarkers Identify Three *Mesozoic* Oil Families

- ***Triassic* Family I:** 8 oils in Triassic-Permian reservoirs; extended tricyclic terpane ratio (ETR) > 2; C_{29}/C_{30} hopane ~0.5 in north, ~1 in south; no bicadinanes, high triaromatic dinosteroids
- ***Upper Jurassic* Family V:** 3 oils in Triassic-Permian reservoirs; ETR < 2, high bicadinanes and triaromatic dinosteroids (Bazhenov equivalent)
- ***Lower-Middle Jurassic* Family VI:** 4 oils in Lower-Middle Jurassic reservoirs; ETR < 2, high bicadinanes and triaromatic dinosteroids, high terrigenous markers (Tyumen equivalent)

Notes by Presenter:

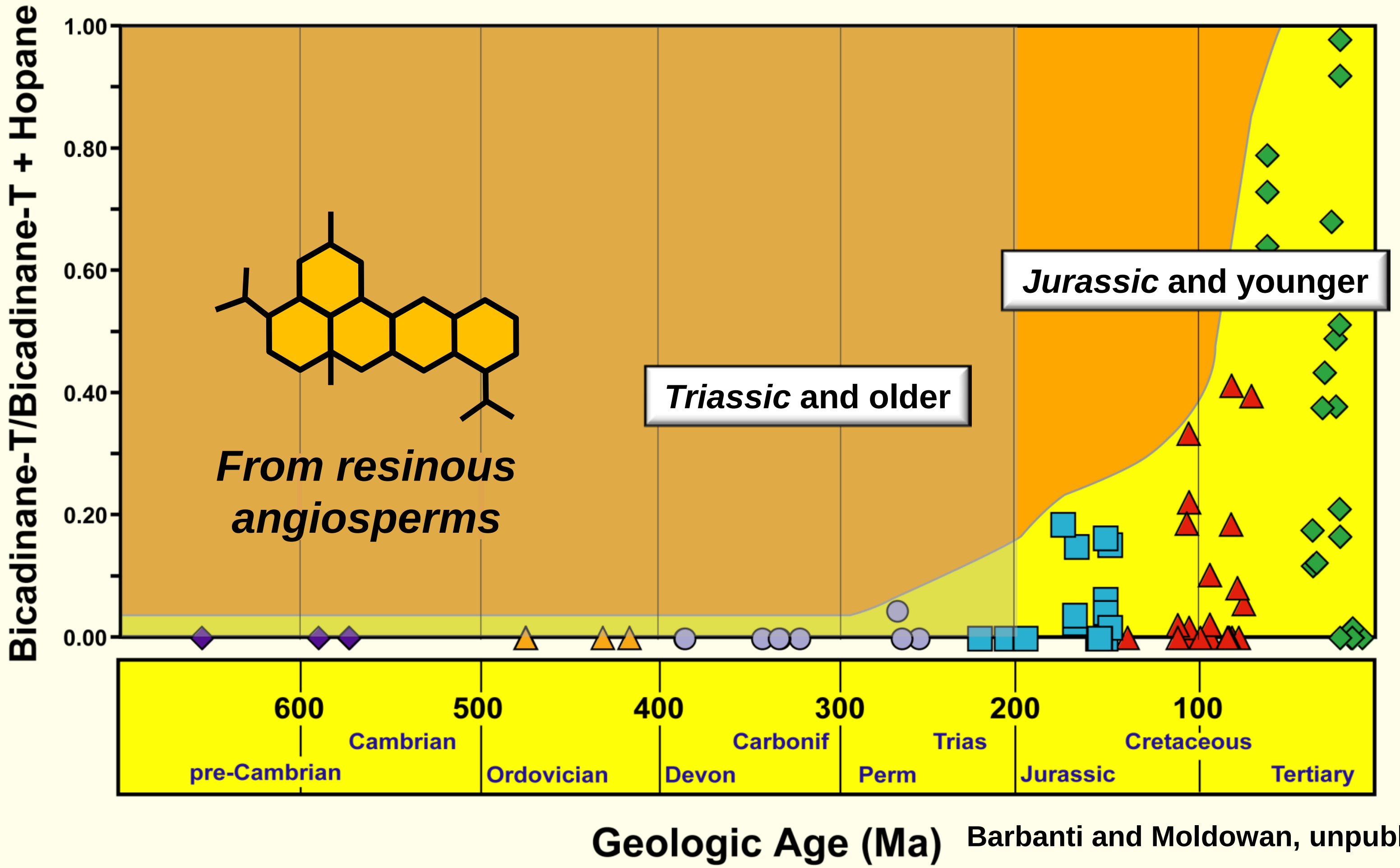
TA-Dino = Triaromatic dinosteranes/(TA-dino+3-methylstigmastane 20R)

TA-DMD3/C_{28}S = Triaromatic 23,24-dimethylcholesteroids (TA-DMC)/C_{28} stigmastane = "C_{28} triaromatic demethyldinosterane/C_{28} stigmastane"



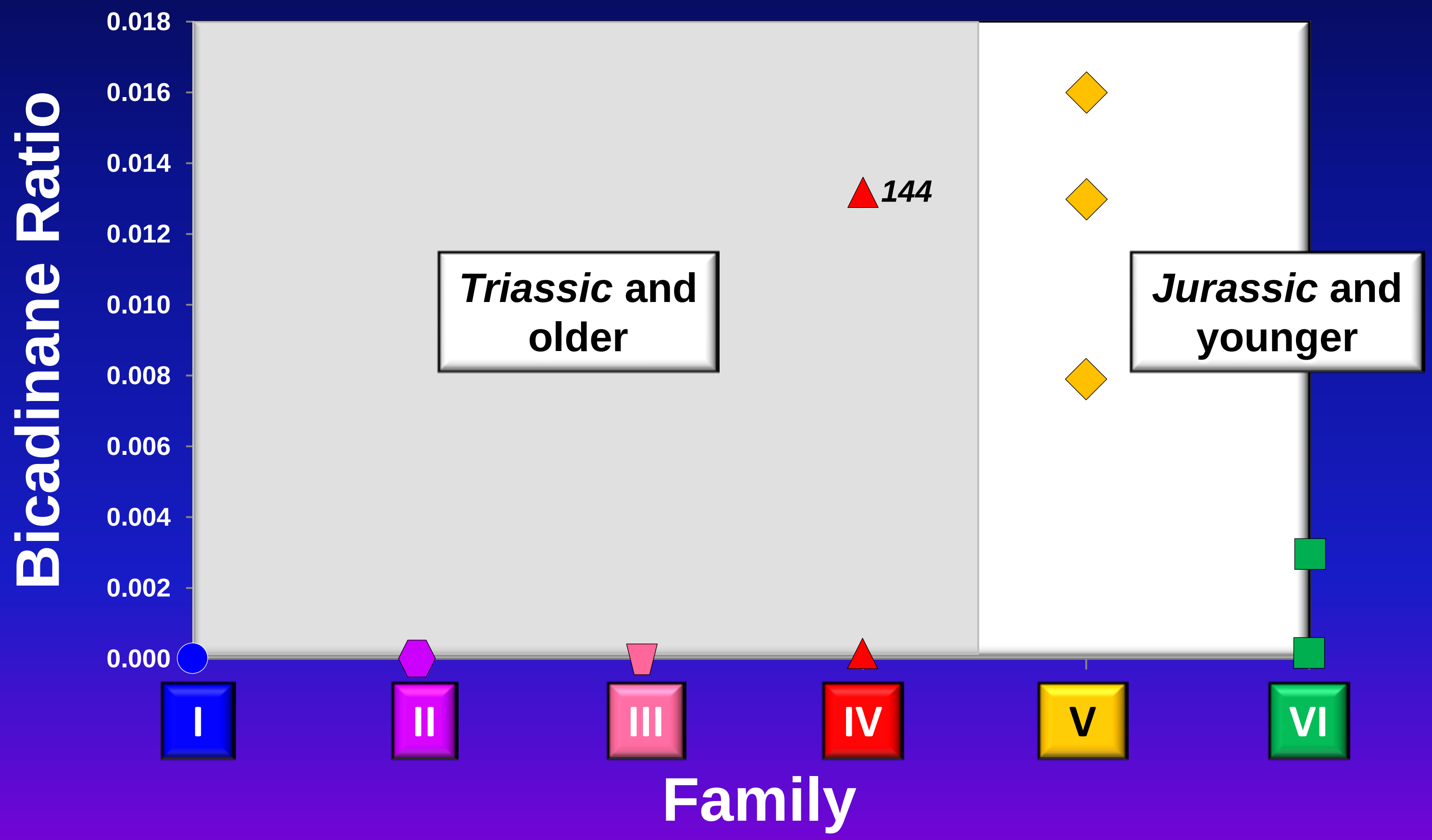
Notes by Presenter:
Holba et al. (2001) studied a suite of worldwide crude oil samples with Triassic or Jurassic source rocks based on geochemical and geological evidence. All Triassic oil samples (39) had ETR ≥2.0, except for three Late Triassic samples from the Adriatic Basin that probably originated from a hypersaline source-rock setting. Early Jurassic oil samples (17) had ETR ≤2.0, except for two samples with slightly higher values. Middle or Late Jurassic oil samples (73) had ETR ≤2.0 with most <1.2 (63). The sharp drop in ETR at the end of the Triassic corresponds to a major mass extinction, which may have had an impact on the principal biological sources of tricyclic terpanes (e.g., *Tasmanites*?).

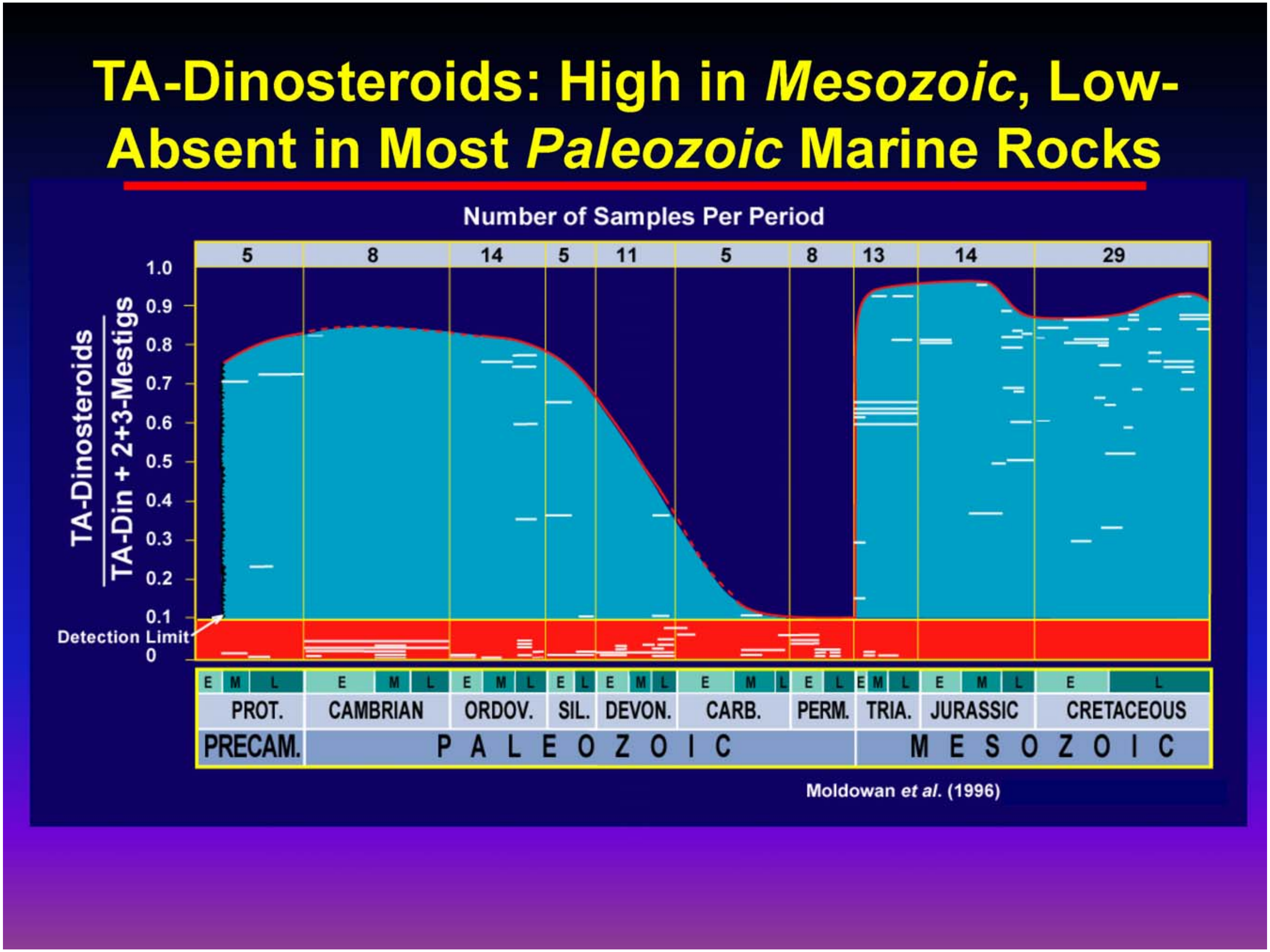
Families V-VI Contain Bicadinanes Indicating *Jurassic* or Younger Source Rock



Barbanti and Moldowan, unpubl.

Families V-VI are from *Jurassic* or Younger Source Rocks with Terrigenous Input

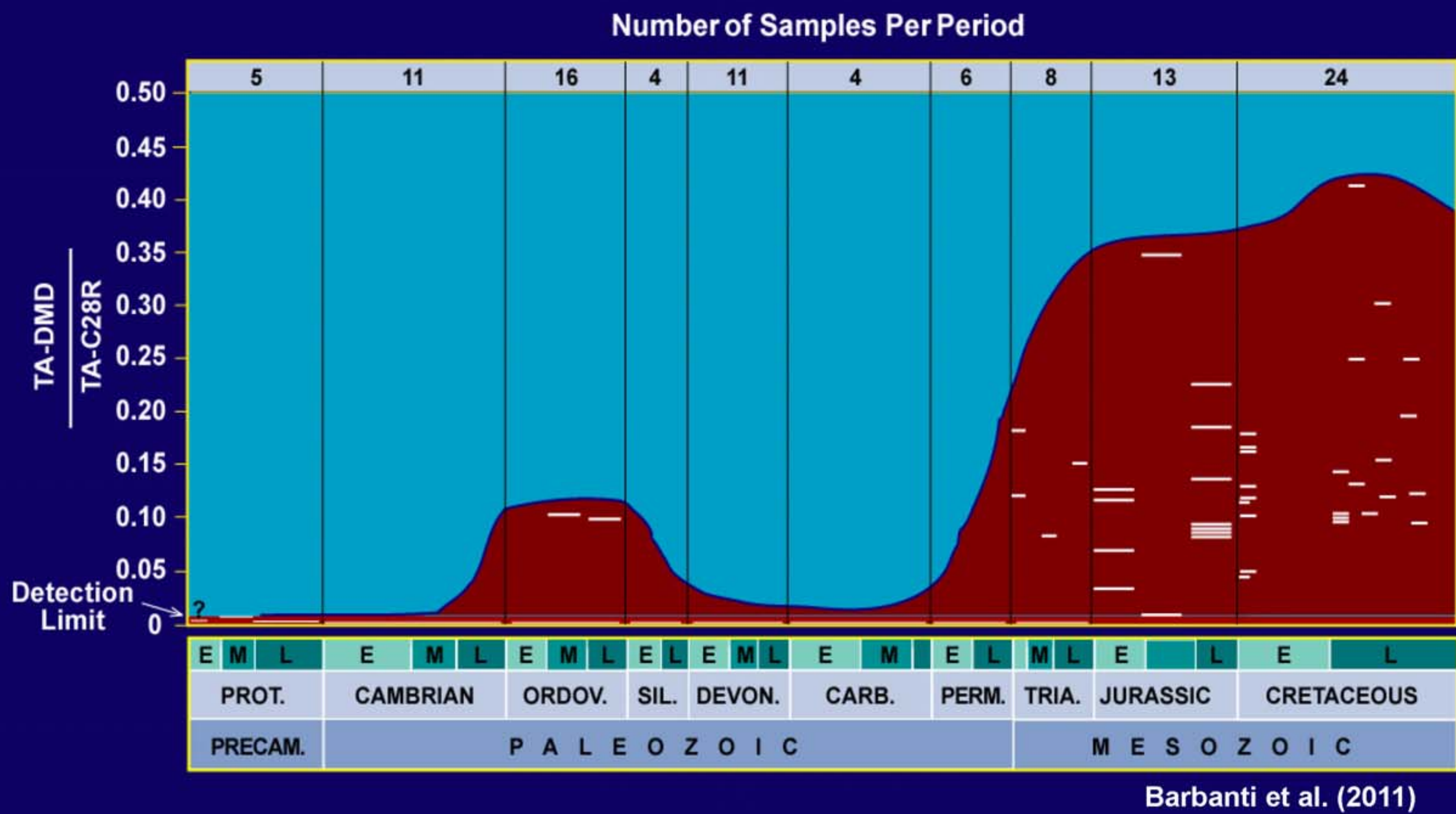




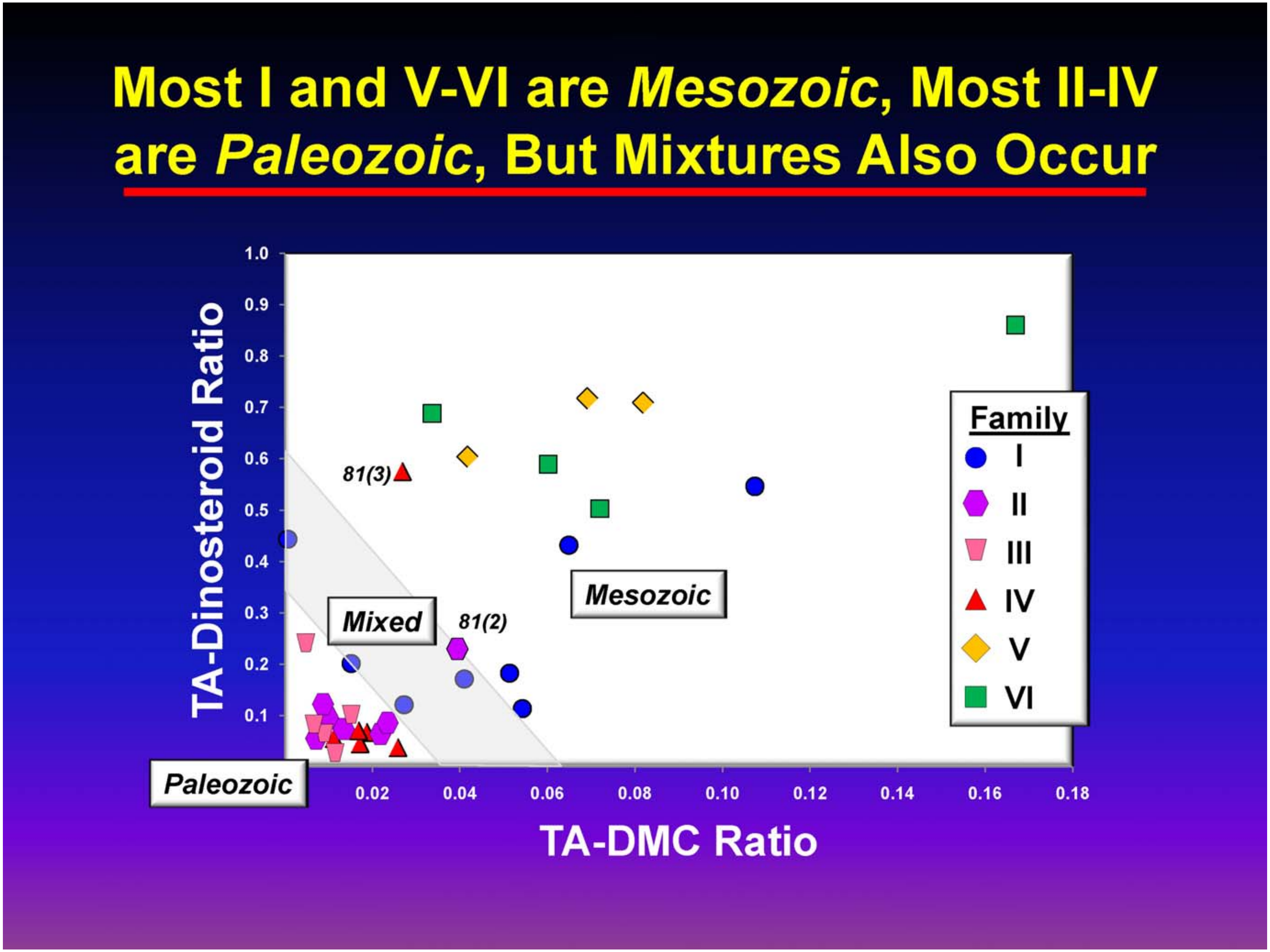
Notes by Presenter:

Note: The TA-Dino on the y-axis in the figure is not exactly the same as our TA-Dino = Triaromatic dinosteranes/(TA-dino+3-methylstigmastane 20R)

TA 23,24-Dimethylcholesteroids: High in *Mesozoic*, Low-Absent in *Paleozoic*

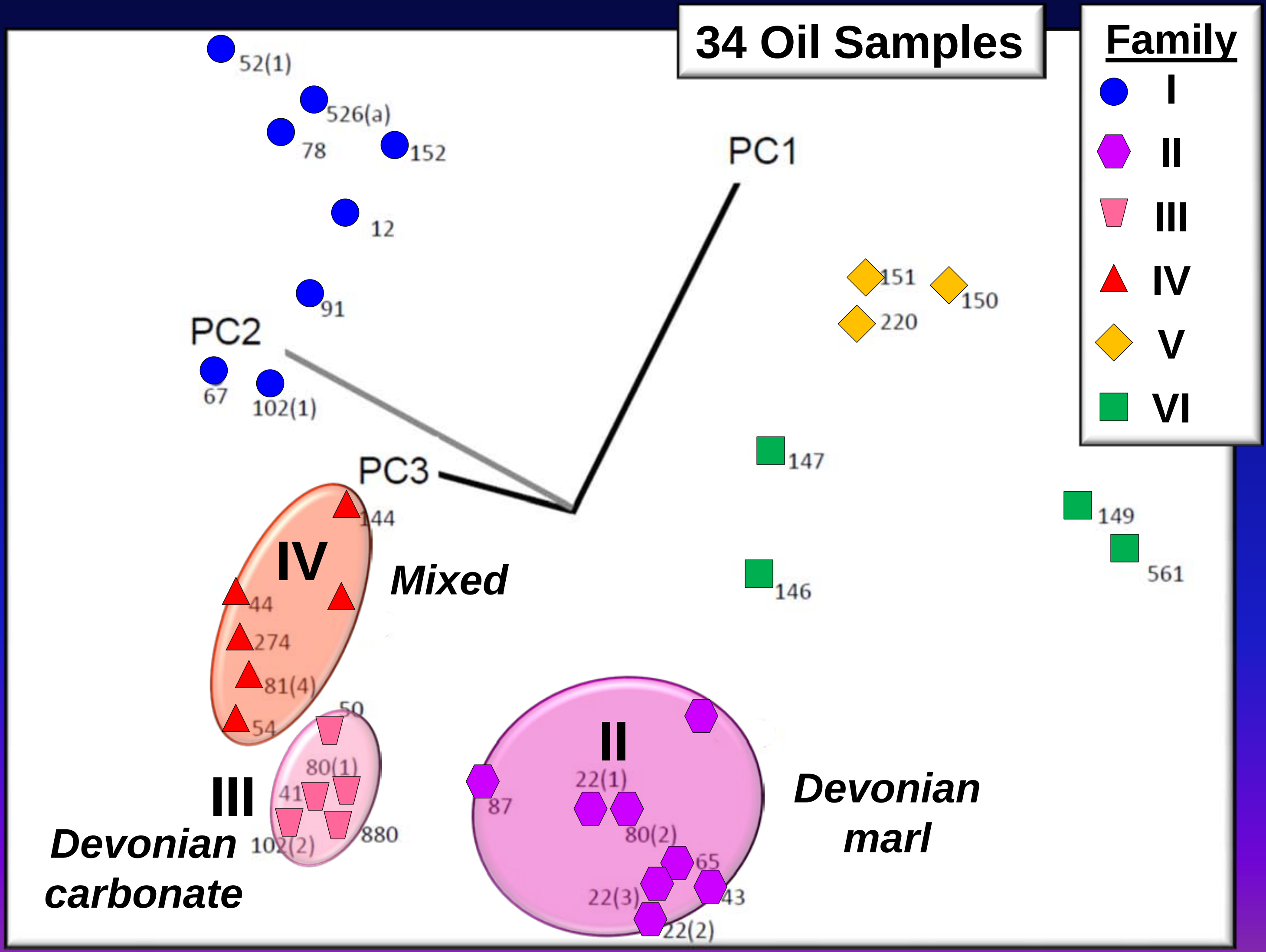


Notes by Presenter: TA-DMD3/C_{28}S = Triaromatic 23,24-dimethylcholesteroids (TA-DMC)/C_{28} stigmastane = "C_{28} triaromatic demethyldinosterane/C_{28} stigmastane"

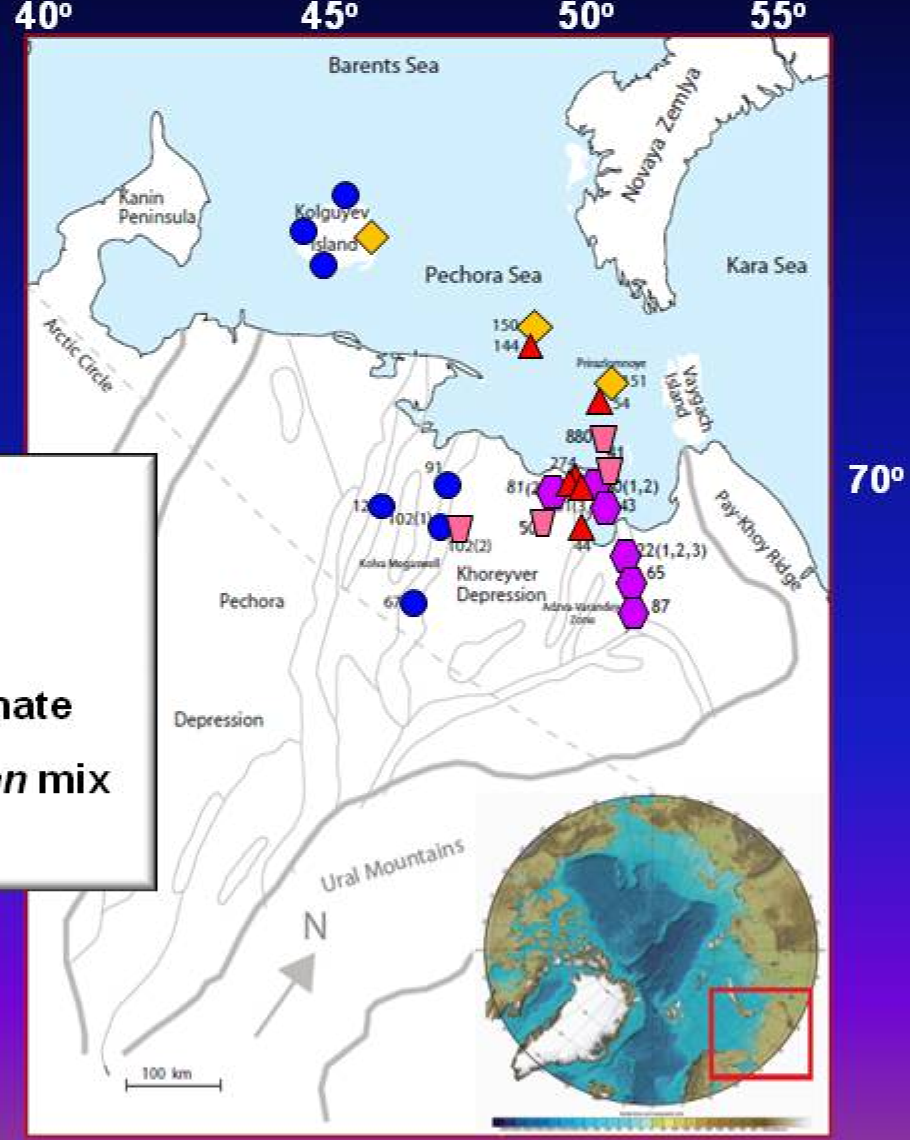


Notes by Presenter: Triaromatic dinosteroids (dinoflagellates) are abundant in Mesozoic and undetected or in low abundance in most Paleozoic marine rock extracts

PCA of 22 Source-Related Biomarker and Isotope Ratios Identifies Six Oil Families



Families I-V Occur on the Pechora Shelf and in the Timan-Pechora Basin



Family

- I) *Triassic*
- II) *Devonian* marl
- III) *Devonian* carbonate
- IV) *Triassic-Devonian* mix
- V) *Upper Jurassic*

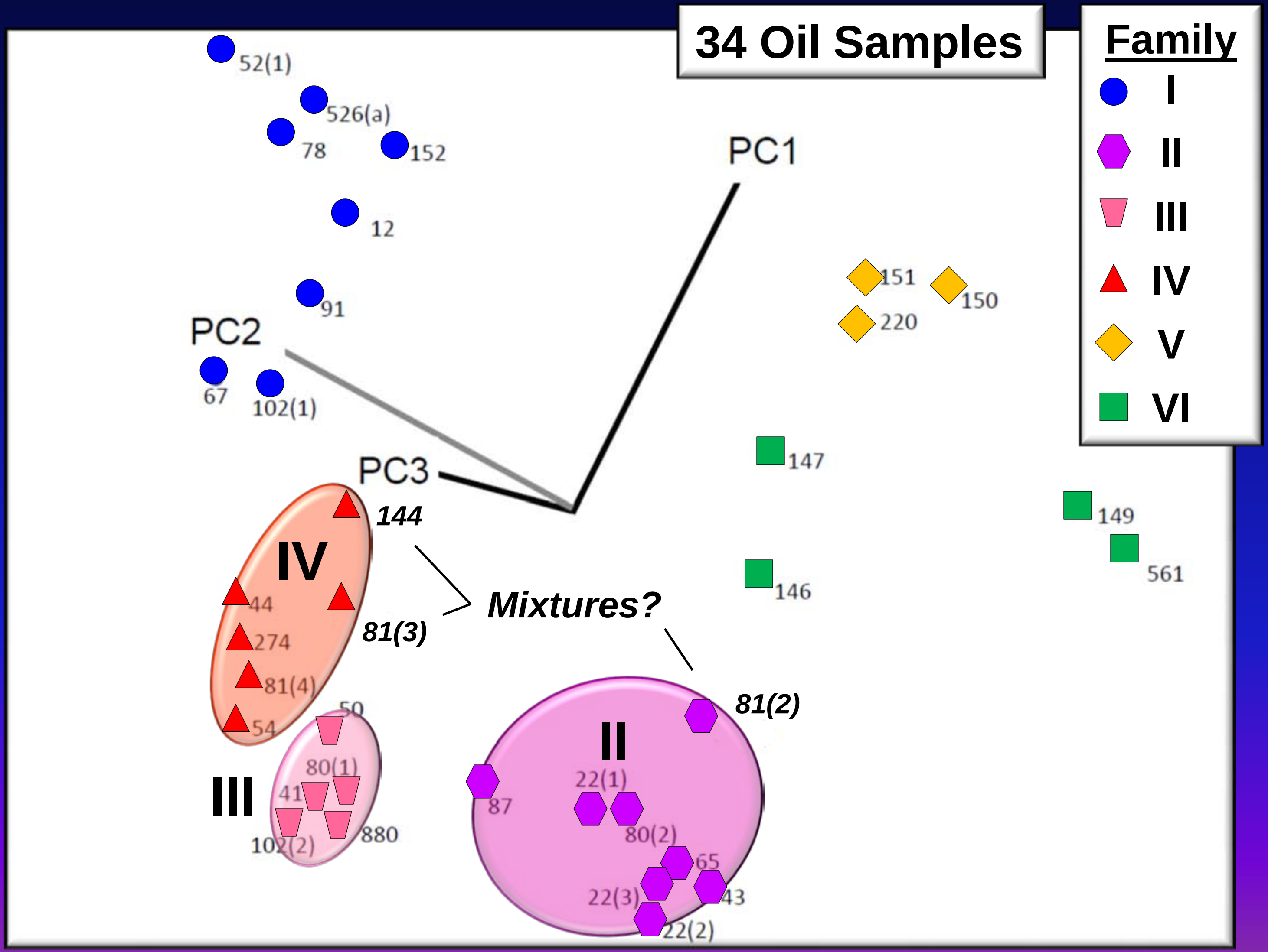
Modified from Ulmishek (1982) and Lindquist (1999)

Source- and Age-Related Biomarkers: One *Mixed*, Two *Paleozoic* Oil Families

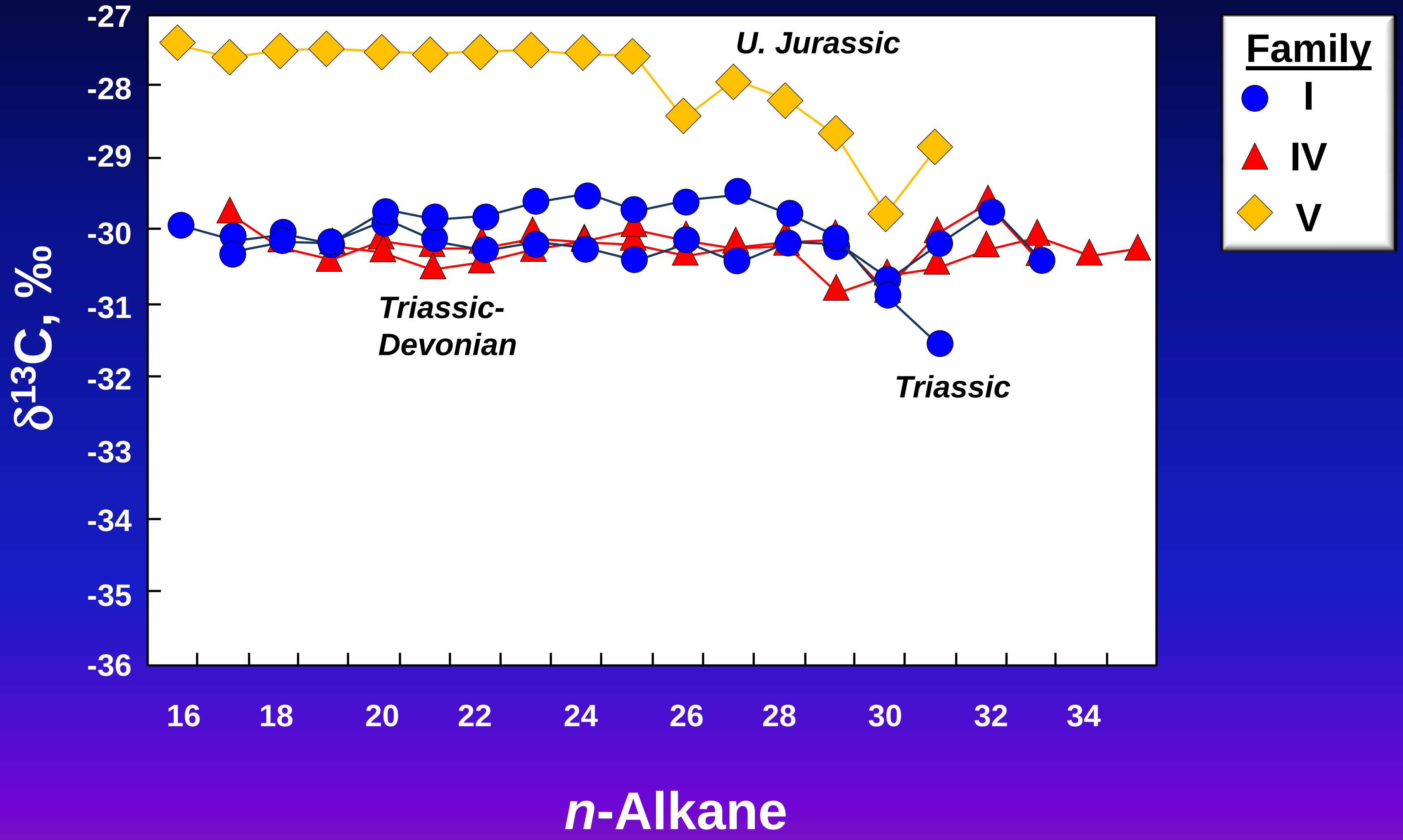
- ***Devonian*** **Domanik Family II (marl):** 8 oils in Devonian reservoirs; ETR < 2; C_{29}>C_{30} hopane; no bicadinanes, low triaromatic dinosteroids; Pr/Ph > 1, no elevated C_{34} hopanes
- ***Devonian*** **Domanik Family III (carbonate):** 5 oils in Permian-Devonian reservoirs; ETR < 2; C_{29}>>C_{30} hopane; no bicadinanes, low triaromatic dinosteroids; Pr/Ph < 1, elevated C_{34} hopanes
- ***Triassic-Devonian Mix*** **Family IV:** 6 oils in Permian-Devonian reservoirs; ETR > 2, $C_{29} \geq C_{30}$ hopane; no bicadinanes, low triaromatic dinosteroids; Pr/Ph > 1

Notes by Presenter:
TA-Dino = Triaromatic dinosteranes/(TA-dino+3-methylstigmastane 20R)
TA-DMD3/C_{28}S = Triaromatic 23,24-dimethylcholesteroids (TA-DMC)/C_{28} stigmastane = "C_{28} triaromatic demethyldinosterane/C_{28} stigmastane"

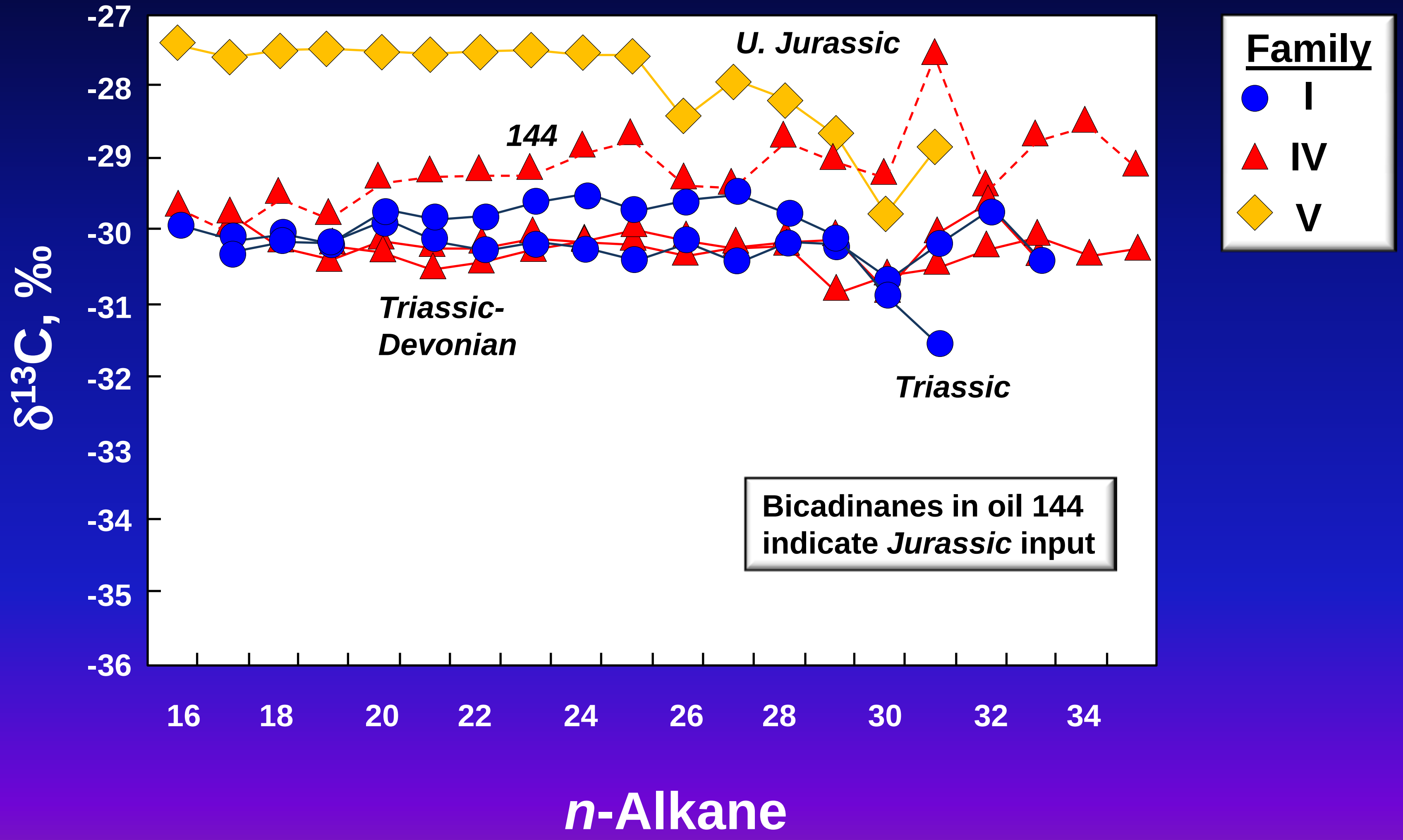
PCA Identifies Several Oil Samples that May Represent Mixtures



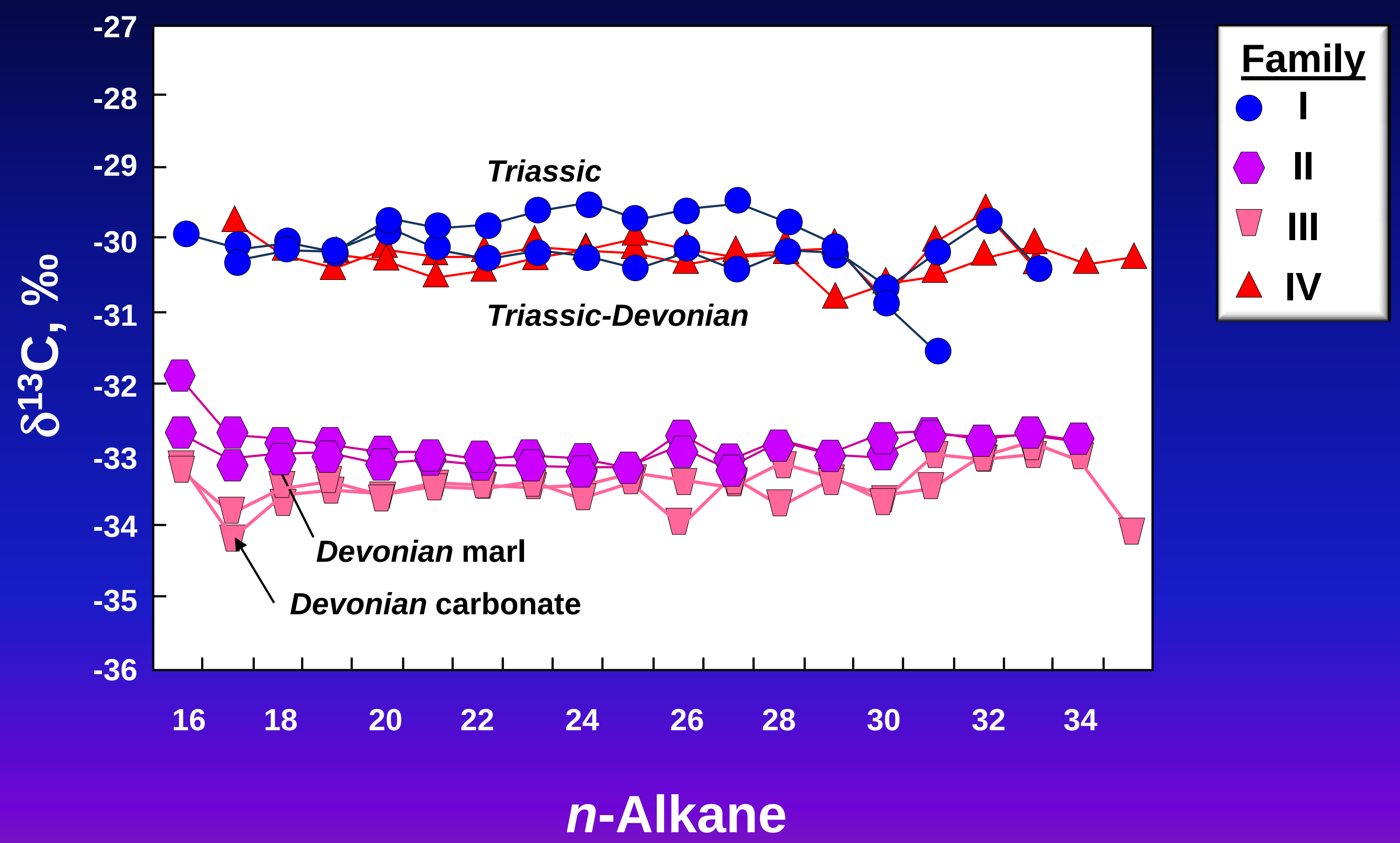
Families I (*Triassic*) and IV (Mixed) are Isotopically Distinct from V (*Jurassic*)



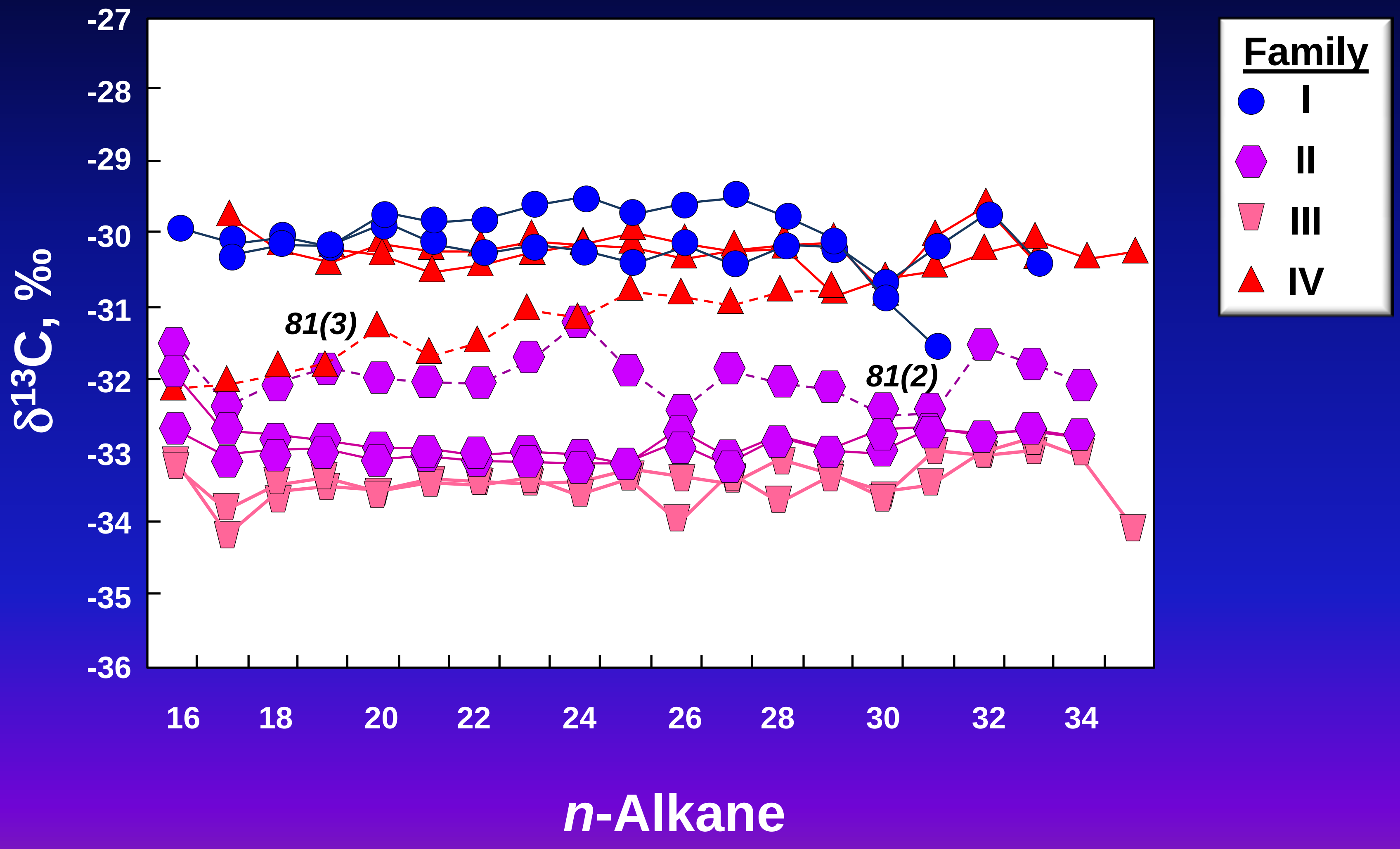
Oil 144 is a Mixture of Families I and V



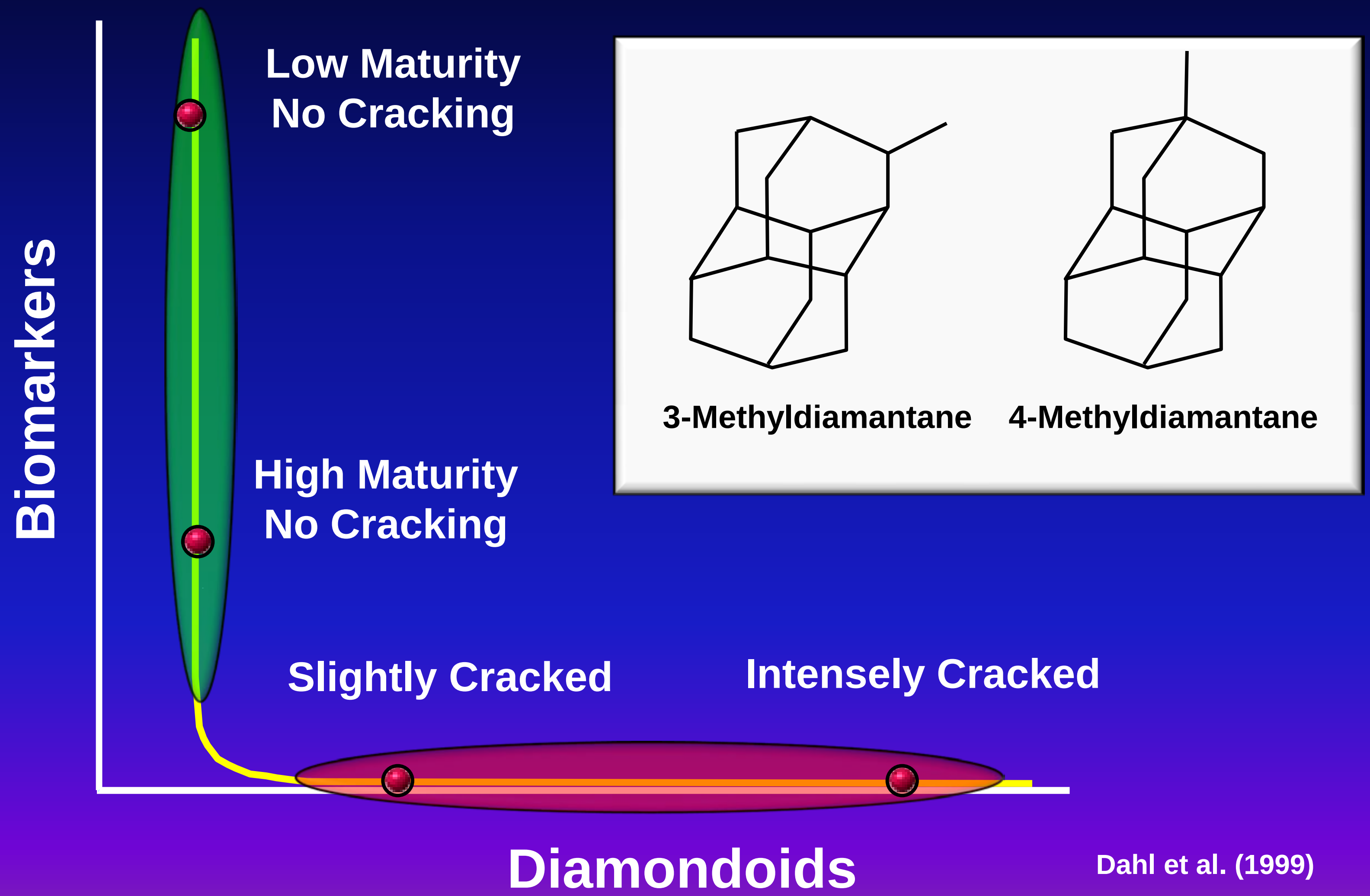
Families I (*Triassic*) and IV (Mixed) are Distinct from II and III (*Devonian*)



Oils 81(2) and 81(3) are Mixtures of *Triassic* (I) and *Devonian* (II, III) Input

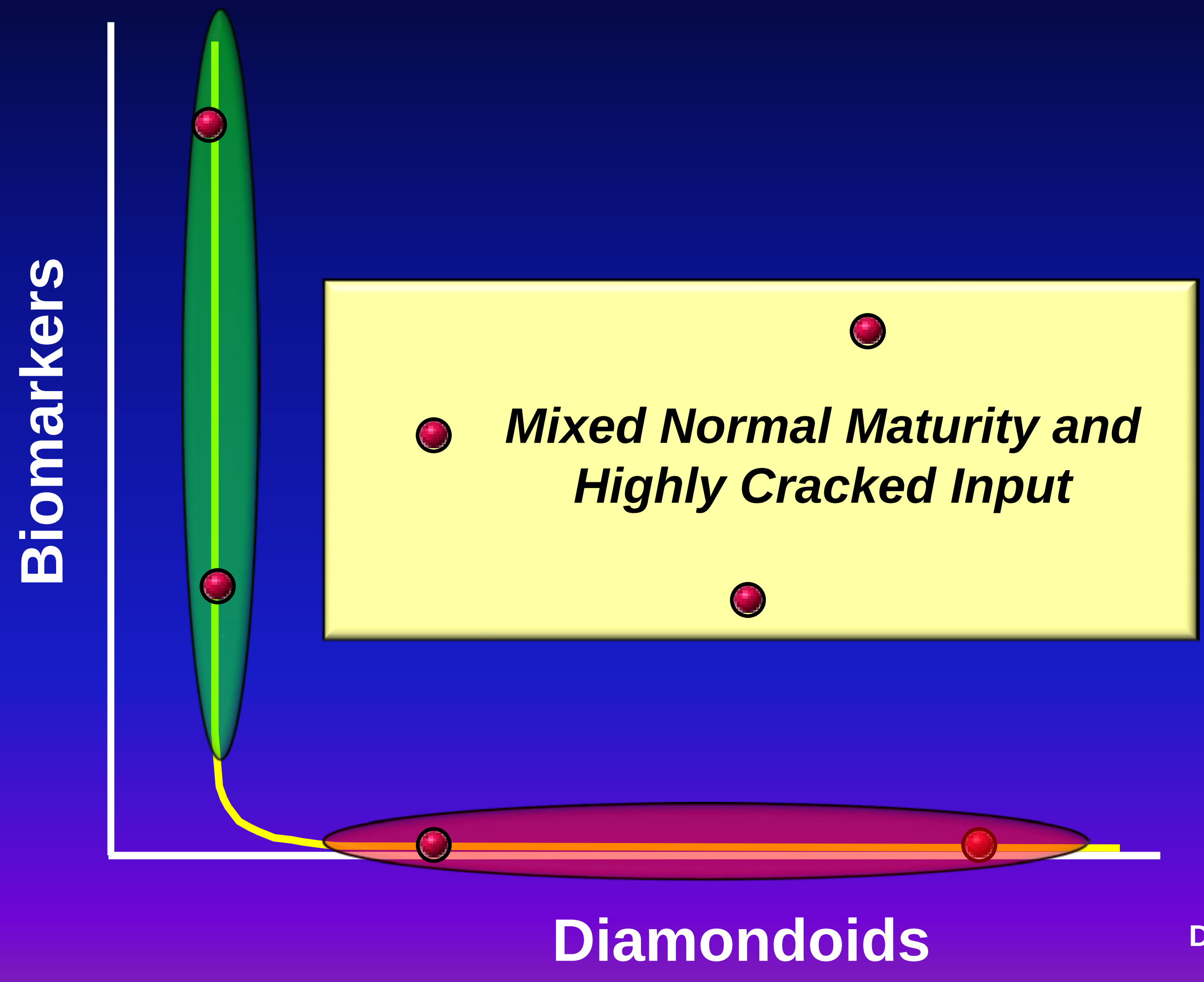


Diamondoids Concentrations Increase During Cracking of Petroleum



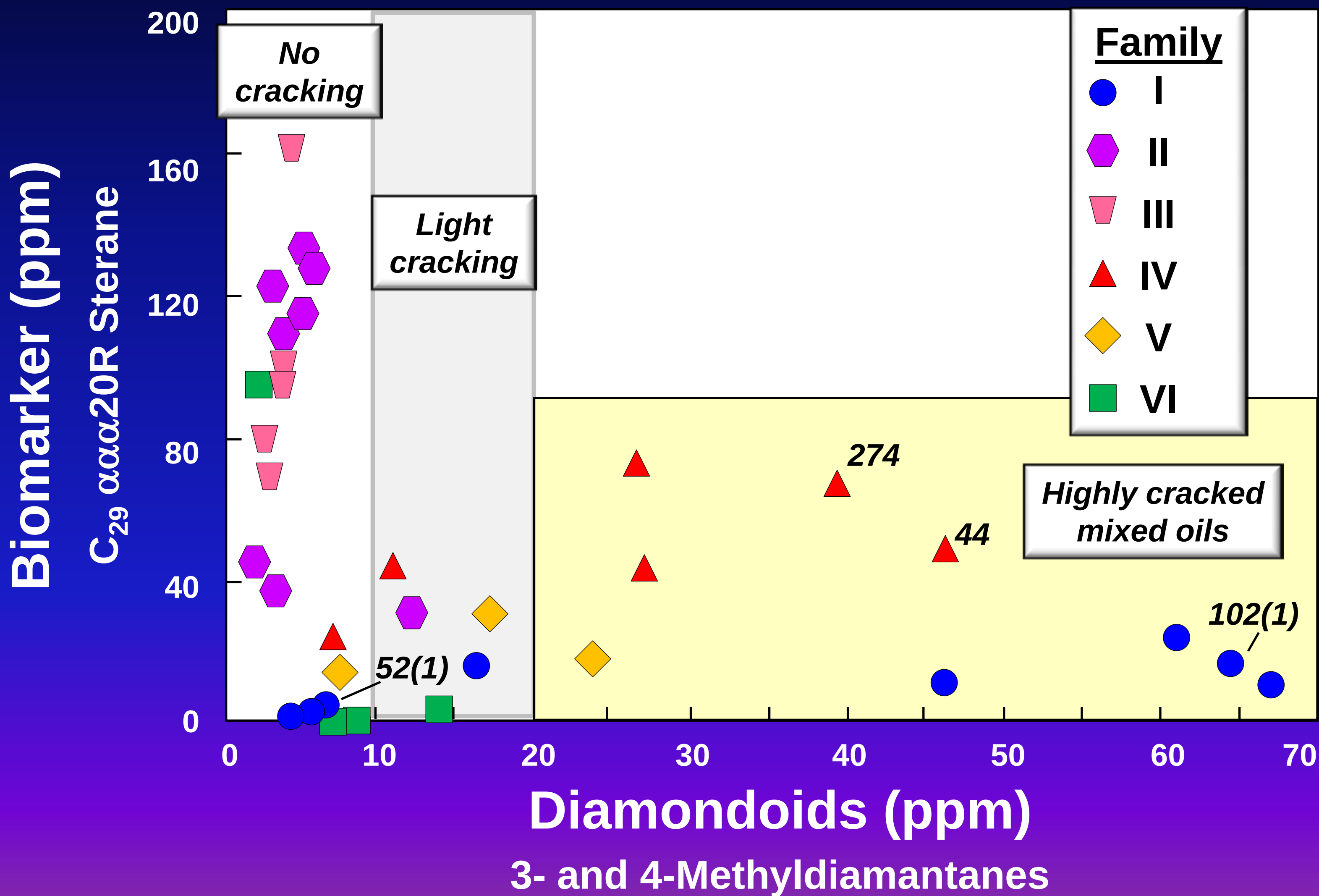
Dahl et al. (1999)

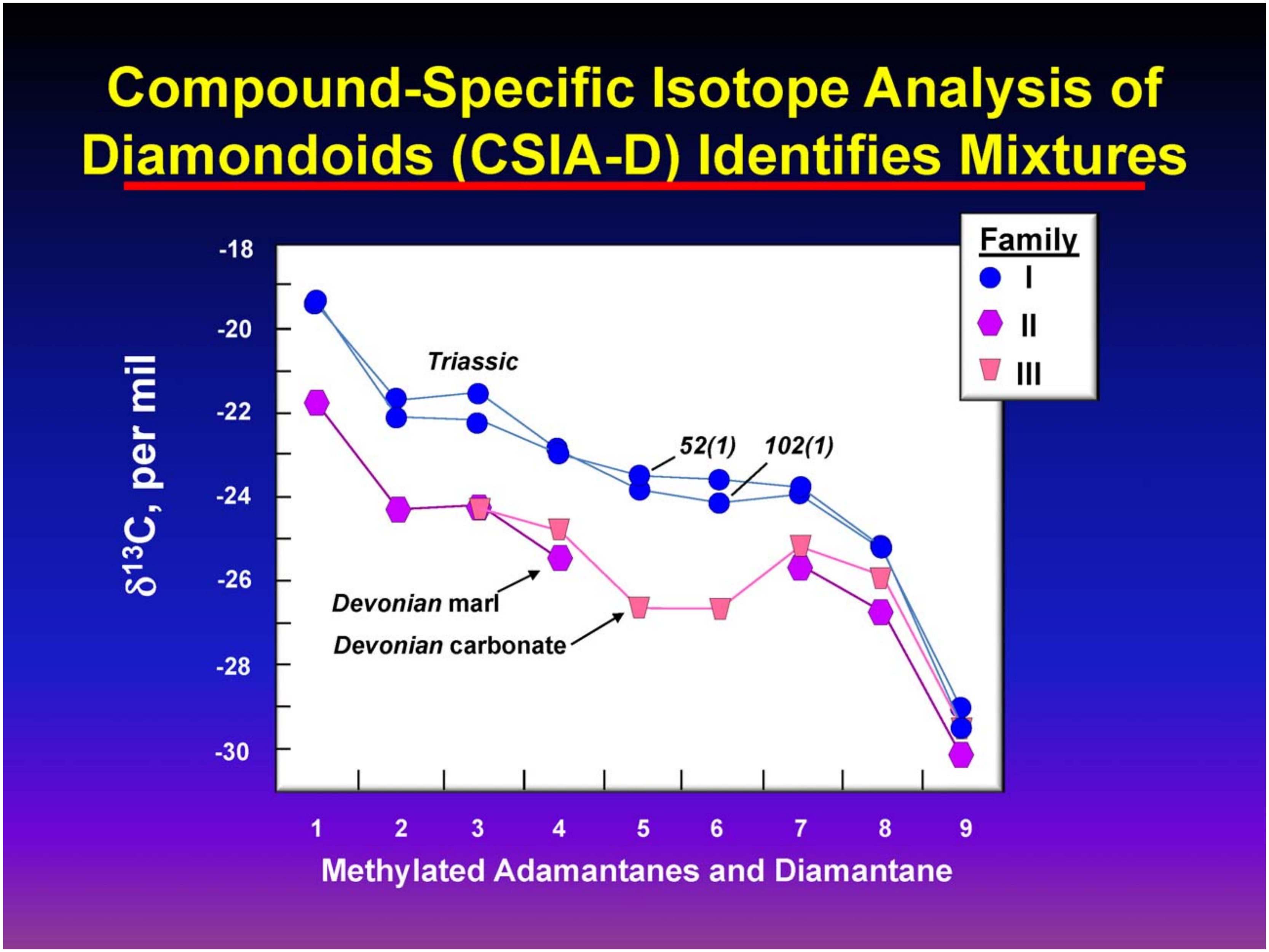
Diamondoid Plot Identifies Mixtures of Mature and Highly Cracked Oil



Dahl et al. (1999)

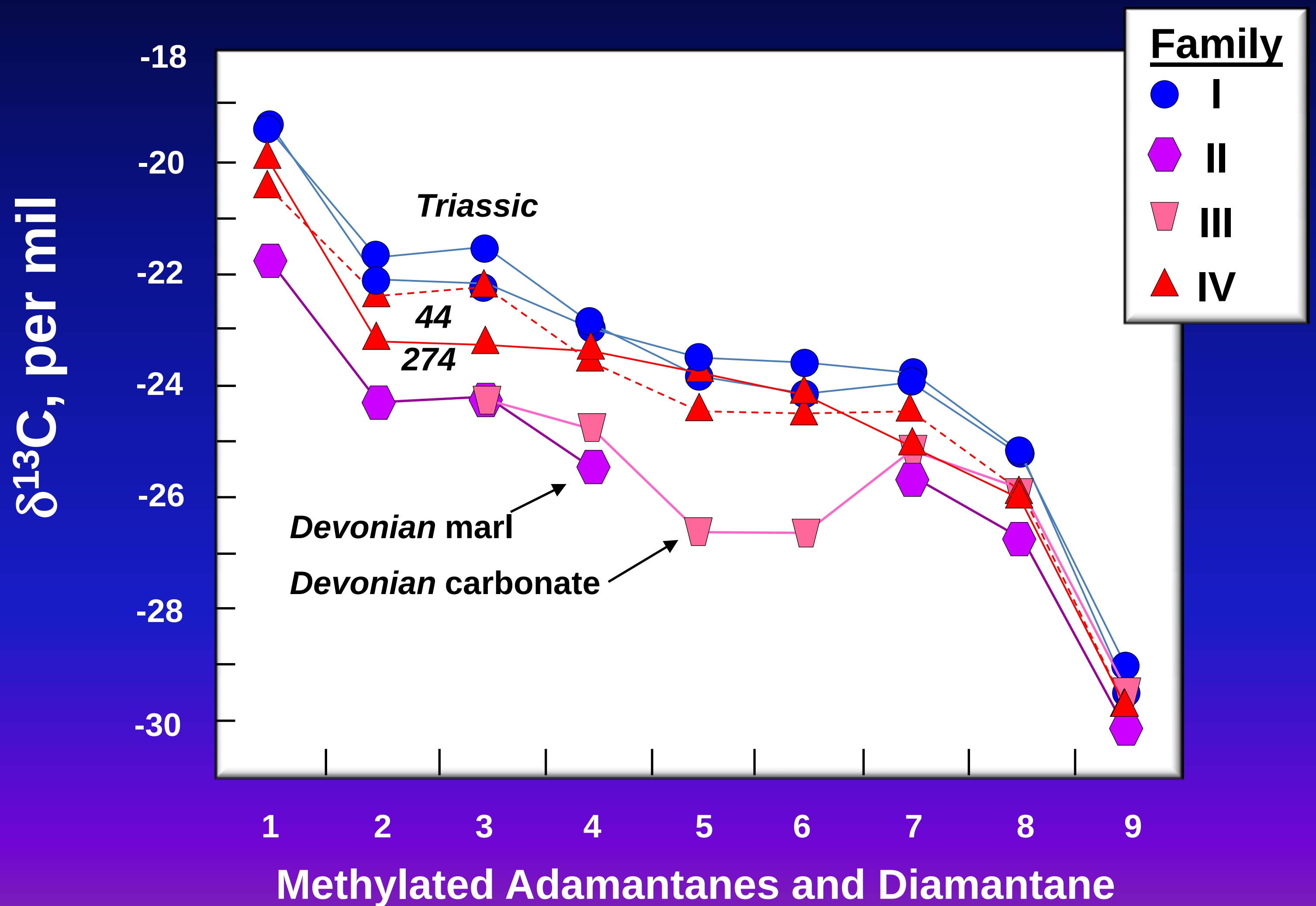
Many Samples are Mixtures Containing Mature Oil and Highly Cracked Products





Notes by Presenter:
1=1-methyladamantane, 2=1,4-dimethyladamantane(cis), 3=1,4-dimethyladamantane(trans), 4=1,3-dimethyladamantane, 5= 1,3,4-trimethyladamantane(cis), 6= 1,3,4-trimethyladamantane(trans), 7=1,3,6-trimethyladamantane, 8=1,3,5-trimethyladamantane, 9= 3-dimethyldiamantane

Oils 44 and 274 are Mixtures of Triassic with Highly Cracked Devonian Input



3P Arctic Conference & Exhibition

Halifax, Nova Scotia; 30 August-2 September, 2011

Arctic Petroleum Systems; 8:55 am Thursday

Conclusions: Six Major Oil Families and Five Source Rocks in the Study Area

	Age	Lithology	Fam	Occurrence	Comment
Mesozoic	Triassic	Shale(N) Marl (S)	I	Widespread in Barents Sea, Timan-Pechora (Spitsbergen, Kolguyev I., Kolva Megaswell)	Thickens northward on Pechora Shelf; cracked Triassic from one source
Mesozoic	U Jurassic	Shale	V	Pechora Shelf, Kolguyev Island	Bazhenov equivalent; no mixing on Pechora Shelf
Mesozoic	L-M Jurassic	Shale	VI	Barents Sea (Shtokman field, Spitsbergen)	Tyumen equivalent
Paleozoic	Devonian	Marl	II	Timan-Pechora (Adzva-Varandey Zone)	Domanik; deep co-source in Timan-Pechora
Paleozoic	Devonian	Carbonate	III	Timan-Pechora, Pechora Shelf	Domanik; deep co-source in Timan-Pechora
Mixed	Triassic-Devonian	--	IV	Pechora Shelf	Mixed Triassic and deep, high-maturity Domanik

Acknowledgements

Fred Fago, Paul Lipton, Shaun Moldowan, Peter Denisevich, Ye Wang, David Zinniker, Jeremy Dahl, Robert Dunbar, Dave Mucciarone

- Stanford Molecular Organic Geochemistry Industrial Affiliates (MOGIA)
- Stanford Basin and Petroleum System Modeling (BPSM) Industrial Affiliates

3P Arctic Conference & Exhibition

Halifax, Nova Scotia; 30 August-2 September, 2011

Arctic Petroleum Systems; 8:55 am Thursday

References

- Barbanti, S.M., J.M. Moldowan, D.S. Watt, and E. Kolaczkowska, 2011. New triaromatic steroids distinguish Paleozoic from Mesozoic oil. Organic Geochemistry 42: 409-424.
- Dahl, J.E.. J.M. Moldowan, K.E. Peters, G.E. Claypool, M.A. Rooney, G.E. Michael, M.R. Mello, and M.L. Kohnen, 1999. Diamondoid hydrocarbons as indicators of natural oil cracking. Nature 399, 55-57.
- Holba, A. G., L. Ellis, I. L. Dzou, A. Hallam, W. D. Masterson, J. Françu, and A. L. Fincannon, 2001. Extended tricyclic terpanes as age discriminators between Triassic, Early Jurassic and Middle-Late Jurassic oils: 20th International Meeting on Organic Geochemistry, p. 464.
- Dore, A.G., 1995. Barents Sea geology, petroleum resources and commercial potential. Arctic 48, 207-221.
- Lindquist, S.J., 1999. The Timan-Pechora Basin province of northwest Arctic Russia: Domanik-Paleozoic total petroleum system. USGS Open-File Report 99-50-G, 24 p.
- Moldowan, J.M., S.R. Jacobsen, B.J. Huizinga, D.S. Watt, K.E. Peters, and F. Fago, 1996. Chemostratigraphic reconstruction of biofacies: Molecular evidence linking cyst-forming dinoflagellates with pre-Triassic ancestors. Geology 24, 159-162.
- Peters, K.E., C.C. Walters, and J.M. Moldowan, 2005. The Biomarker Guide. Cambridge University Press, Cambridge, U.K., 1155 p.
- Ulmishek, G., 1985. Petroleum geology and resource assessment of the Timan-Pechora Basin, USSR, and the adjacent Barents-northern Kara shelf. Argonne National Laboratory Energy and Environmental System Division Report ANL/EES-TM-199, p. 197.