A 2-D Petroleum System Model for the Vallecitos Syncline, San Joaquin Basin, California *

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Abstract

The Vallecitos Syncline is a westerly structural extension of the San Joaquin Basin. Dispersed oil accumulations in the Vallecitos area make oil and gas exploration challenging. Our earlier 1D model indicated that there could be two active source rocks in the syncline: the Eocene Kreyenhagen Formation and Cretaceous Moreno Formation.

Biomarker analysis was conducted on 15 oil samples from the syncline. Source-related biomarkers show two genetic groups, which may originate from two different source rocks. Diamondoid analyses for those samples indicate mixtures of oil-window maturity and high maturity oils. A deep, high-maturity source was strongly suggested based on the geochemical features of the samples.

A 2D line along a published cross-section through the deepest part of the syncline was selected to conduct thermal history, basin evolution, and migration analyses. Stratigraphic evidence and modeling suggest that several recent episodes of erosion are required due to folding that removed significant overburden. Thick (~ 2 km) overburden rock in the syncline pushed shallow Eocene Kreyenhagen source rock into the oil window around 14 Ma. In contrast, the Cretaceous Moreno source rock reached extremely high maturity (dry gas window) at same time.

Results suggest that in the Vallecitos Syncline the bottom and the top of the Cretaceous Moreno Formation reached thermal maturity at 37 Ma and 18 Ma, respectively. The synclinal Eocene Kreyenhagen Formation became thermally mature at 14 Ma. The 2D model results indicate that the Kreyenhagen Formation has a maximum transformation ratio (TR) of 50% at its base, whereas the Moreno Formation has TR~100%. These results are supported by biomarker and diamondoid geochemistry, which indicate that the Kreyenhagen oils contain a high-maturity component that could originate from the Moreno Formation. The results are consistent with our earlier 1D burial history

model in the Vallecitos Syncline. Compound-specific isotope analysis (CSIA) and quantitative extended diamondoid analysis (QEDA) were employed to confirm correlations and determine oil mixtures.

Migration analysis on our 2D profile indicates hydrocarbon loss on both flanks of the cross-section. Effective traps are absent in the cross-section and most of the generated hydrocarbons probably migrated out of the model along strike or perpendicular to it. A future 3D model could better explain the main migration pathways, if additional structural data become available.

References

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Peters, K.E., and J. M. Moldowan, (eds.), 1993, The biomarker guide; interpreting molecular fossils in petroleum and ancient sediments: Prentice Hall, Engelwood Cliffs, N.J., 363 p.

Scheirer, A.H., 2007, Petroleum systems and geologic assessment of oil and gas in the San Joaquin Basin Province, California: U.S. Geological Survey Professional Paper 1713, available on CD-ROM from USGS.

April, 2012
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Long Beach, California

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Leslie Magoon,
Carolyn Lampe
Kenneth Peters

Presenter's notes: Good morning, my name is Meng and I am a fourth year PhD student working with Steve and Mike in BPSM. Today, I will show you our 2 D model results and geochemistry results in the Vallecitos Syncline.

As basin modelers, we have to ask ourselves how many total petroleum systems we are going to model before we are building a numerical forward model for a sedimentary basin. The project is a great example to show you how to use geology and geochemistry to demonstrate the total petroleum systems in the study area.

Location map of Vallecitos syncline

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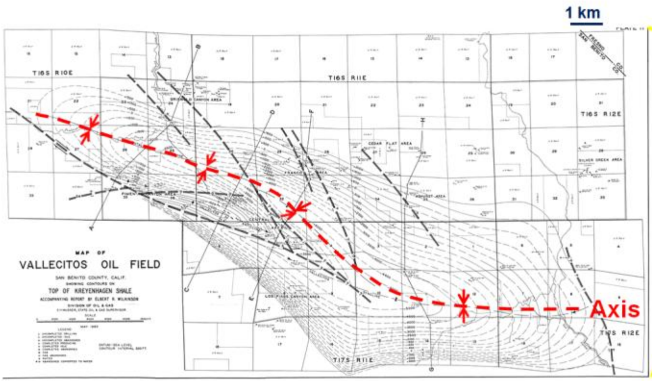
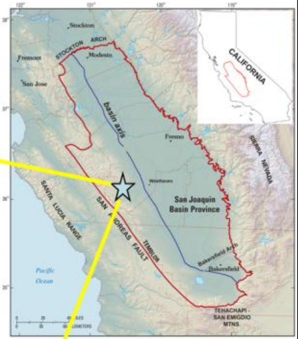
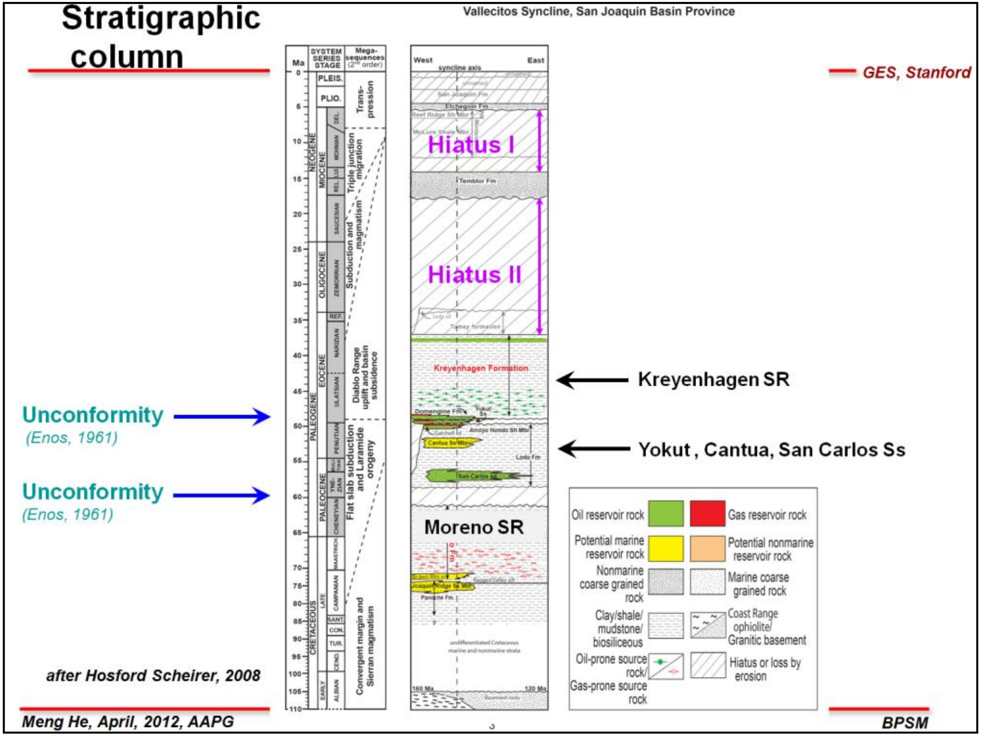
Syncline length:~21km, width: ~5km





after Hosford Scheirer, 2008

Presenter's notes: Here is the location of our study area. It is a small forearc basin and located in the west central part of the San Joaquin Basin. The tectonic activities in this area, dominated by the San Andreas Fault, make the subsurface geology of Vallecitos Sycnline complicated. However, there is renewed interest of oil and gas exploration due the increasing price of oil.



Presenter's notes: There were two significant unconformities at 60 and 50 Ma, and two hiatus in the Oligocene and Miocene. One significant uplift took place in the Pligocene. There are two marine source rocks in the area: one is EK and the other one is CM. Green color here refers to oil-prone source and the red refers to gas source. One of the main purposes of this study is to document that Moreno is also an oil-prone source rock. The reservoir rocks here are Yokut, Cantua and San Carlos sandstones in the Lodo Formation.

Problems/Motivations

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- Test hypothesis suggested by our earlier 1D model that a deeper oil source rock than Kreyenhagen exists in the Vallecitos syncline
- Evaluate geochemically the possible origin of the oil from the deeper pools and mixed oils
- Refine previous published USGS conclusions based on their 3D model in the Vallecitos syncline. Understand the petroleum systems

Presenter's notes: In this project we would like to propose another source rock which is deeper than EK-CM and determine the oil families in the Vallecitos Syncline. Eventually, we are able to refine the conclusions from the previously published study.

Conclusions:

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2D model results indicate:

- Moreno Formation is a depleted source rock at present-day. The shallow part of formation has oil window maturity. The early generated oil could not be captured by young traps. It is a major source rock for the gas production.
- Lower Kreyenhagen Formation still have oil generation potential. It has various maturities within the formation.
- Moreno and Kreyenhagen formations were active source rocks in the Vallecitos syncline.

Geochemical results indicate:

- There are two oil types in the Vallecitos syncline: Moreno and Kreyenhagen
- We identified two petroleum systems: 1) Kreyenhagen-Yokut(.) 2) Moreno-San Carlos(.)
- Kreyenhagen-Yokut(.) was charged by oil-window maturity oil and high cracking components from the same Kreyenhagen formation.
- Moreno-San Carlos(.) was charged by oil-window maturity oil from shallow part of the Moreno formation.

Presenter's notes: The conclusion is that there are two distinguished oil families in the Vallecitos Syncline and they are sources by EK and CM separately, we propose CM was another active source rock in the Vallecitos Syncline and it is not only gas-prone source rock but also it generate oils. The deepest part of Moreno Formation may be generating gas at present day and the diamondoids work may further prove it. Hopefully we will show the diamondoids results next year.

2D burial history model location

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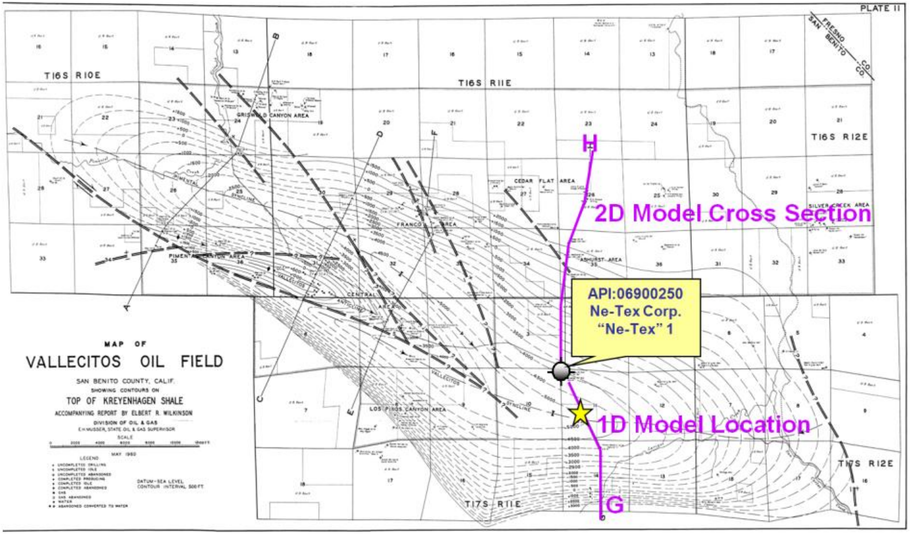

Presenter's notes: Here is the location of our 2D model along the line GH. In addition, if you remember my poster from last year Pacific section in Anaheim, we presented our 1D model in this location which is the deepest part of syncline. The Ne-Tex #1 well is used to calibrate my 1d and 2d models.

Cross-section GH through Vallecitos syncline

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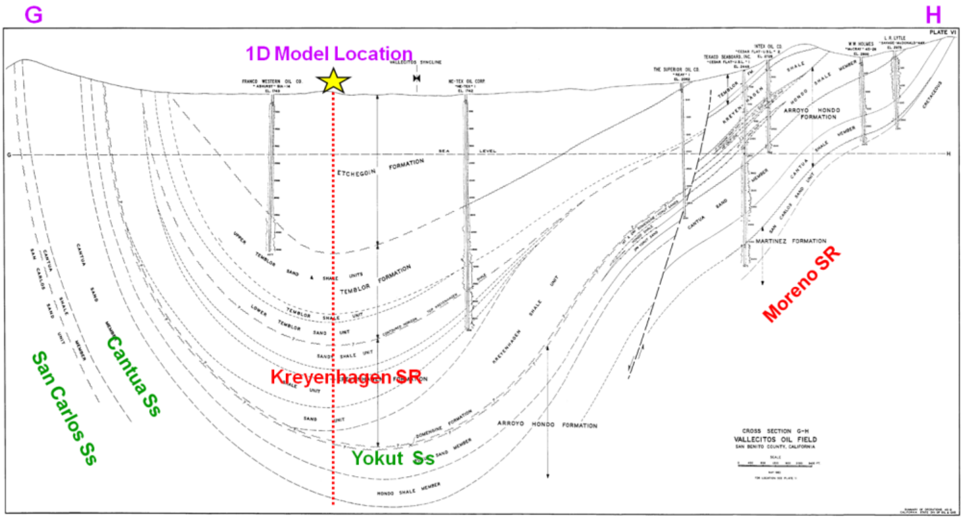


California State Division of Oil and Gas, 1982

Presenter's notes: Here it the cross section of GH where my 2D model is. We know that the actual geology here is more complicated than what we see here, however this is what I have for right now. And we believe that this is enough for the purpose of this study to investigate the thermal history of the syncline.

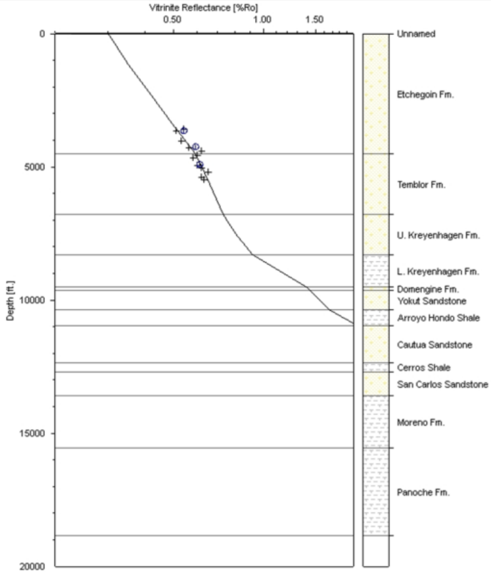
Different HF scenarios

In this project, we are testing 3 HF scenarios

- **"Hot":** HF profile was applied with thermal pulse due to Northward progression of the Mendocino Triple Junction
- **"Cold":** HF profile was applied with low heat flow units due to refrigeration of subducted slab below the syncline
- **"Combo":** HF profile was applied with thermal pulse due to both Northward progression of the Mendocino Triple Junction and refrigeration of subducted slab below the syncline

Presenter's notes: In this project we will be testing three different HF scenarios due to the Mendocino Triple Junction which passed by around 12 Ma and refrigeration of the subducted slab starting around 75 Ma.

Model calibration

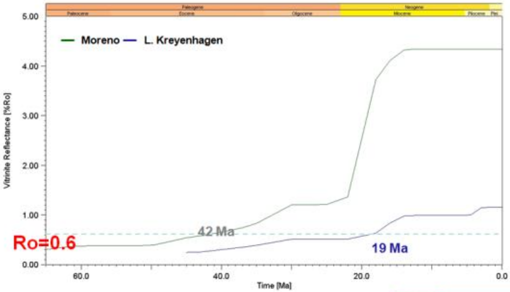


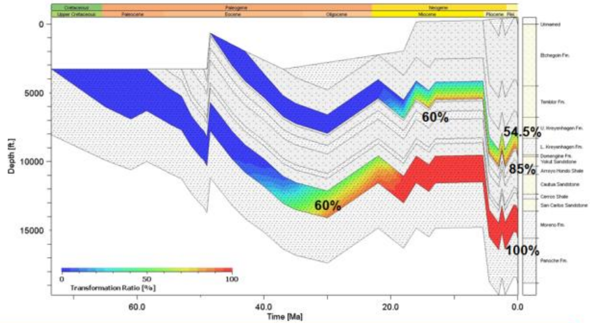
Plot of calculated (line) and measured (symbols) Ro versus depth for the model. Open circle indicates measured Ro data, cross symbol indicates converted Ro from measured Tmax data in well NETEX1.

Summary:

Mendocino Triple Junction
has a significant thermal impact as a hotspot on the thermal history of the Vallecitos syncline.

Previous 1D Model results





Oil samples and locations in the Vallecitos syncline

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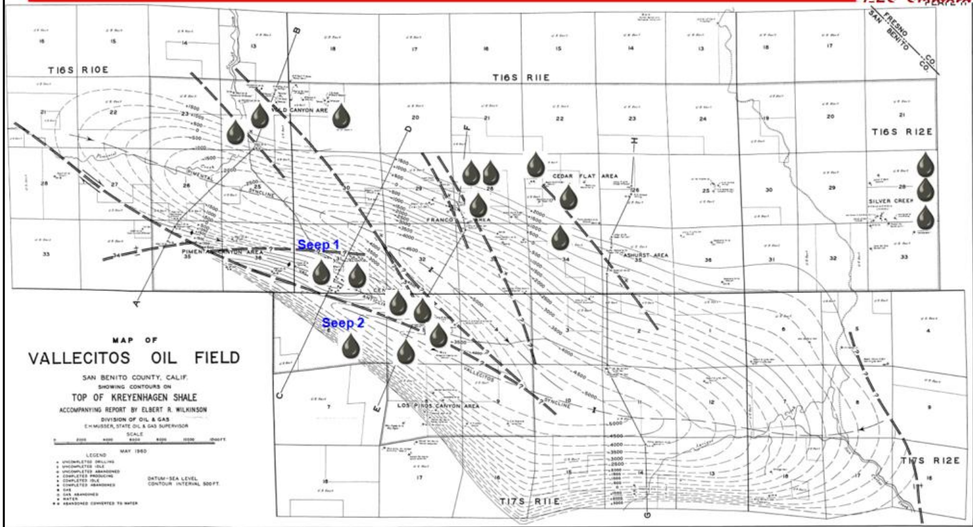

- 23 black oil samples
- 2 oil seep samples
- 1 gas condensate sample

◇ Oil (EK) **Eocene Kreyenhagen**

□ Oil (CM) **Cretaceous Moreno**

Presenter's notes: Here is the total 26 oil samples in the Vallecitos, among them 23 black oil samples, 2 seeps, and 1 gas condensate. I am using the open symbols for all the Vallecitos oils (blue refers to Kreyenhange sourced oil, and red refers to Moreno sourced oil) in the upcoming geochemistry slides in this presentation.

Oil and rock extract to compare with the Vallecitos oils

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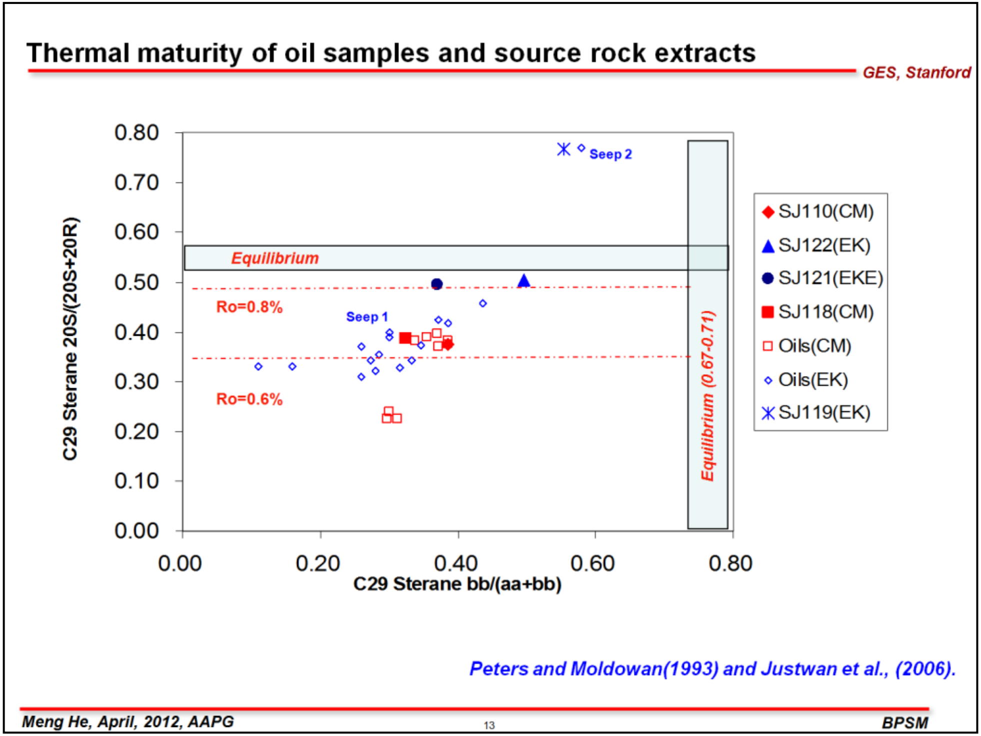
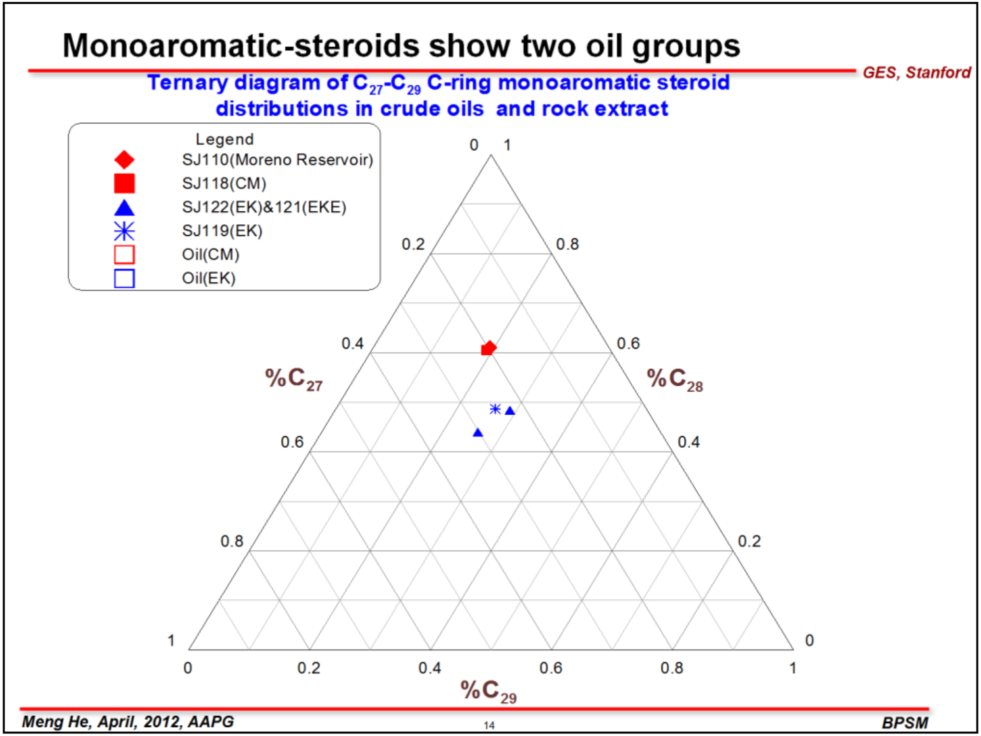
◆ SJ110(CM)	1 oil sample from Moreno Formation and reservoir in the Vallecitos syncline
■ SJ118(CM)	1 oil sample from Moreno Formation in Oil City (CM)
▲ SJ122(EK)	1 oil sample from the Kreyenhagen source rock
⚹ SJ119(EK)	1 oil seep sample from Big Tar Canyon near the Coalinga oil field
× SJ121(EKE)	1 Kreyenhagen source rock extract

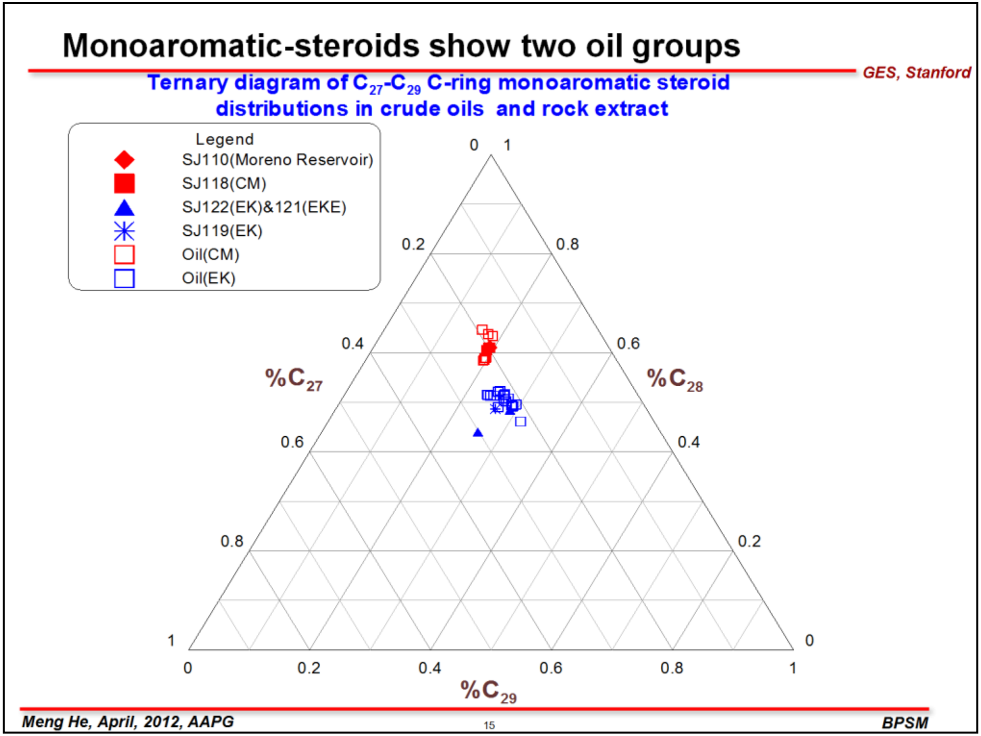
Presenter's notes: Here is the comparison data set in which the origin of those oils have been well studied. That will allow us to be able to build the genetic relationships among the oils in Vallecitos Syncline. This comparison data set will be shown by solid symbols.



Presenter's notes: Here are the maturities for all the oils and source rock extract and they are all in the oil window range. It will give us more confidence in correlating the Vallecitos oils.



Presenter's notes: Here we plot the EK and CM sources oils from our comparison data set by using one biomarker parameter (Monoaromatic steranes) to show how different EK oils are from CM oils. (solid symbol stands for well studies oils in the comparison data set).



Presenter's notes: If we superimpose the Vallecitos oils on the same plot, you can see that they are plotted as two separated groups which look like EK and CM.

Steranes show two oil groups

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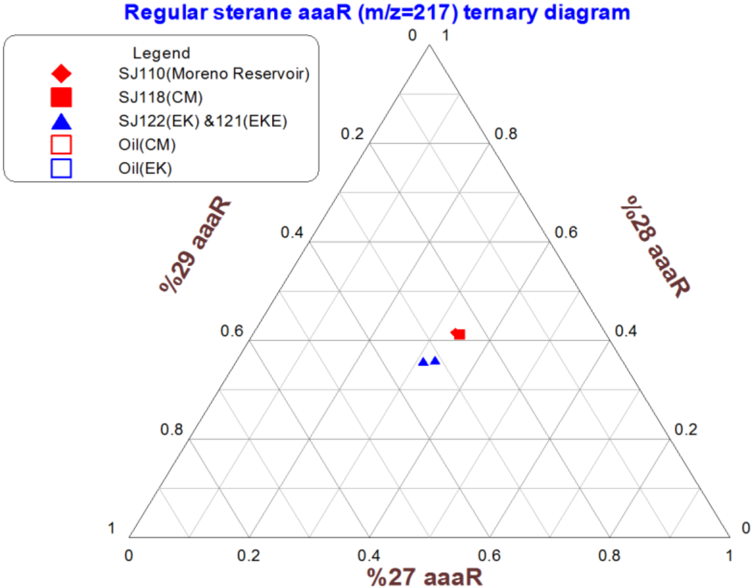
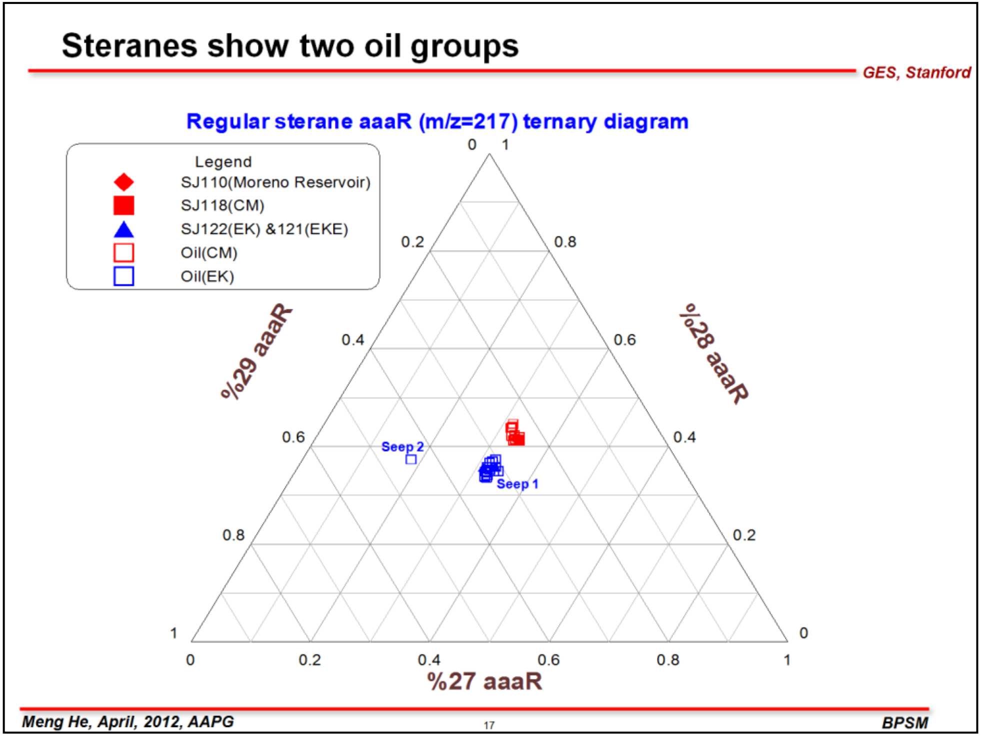
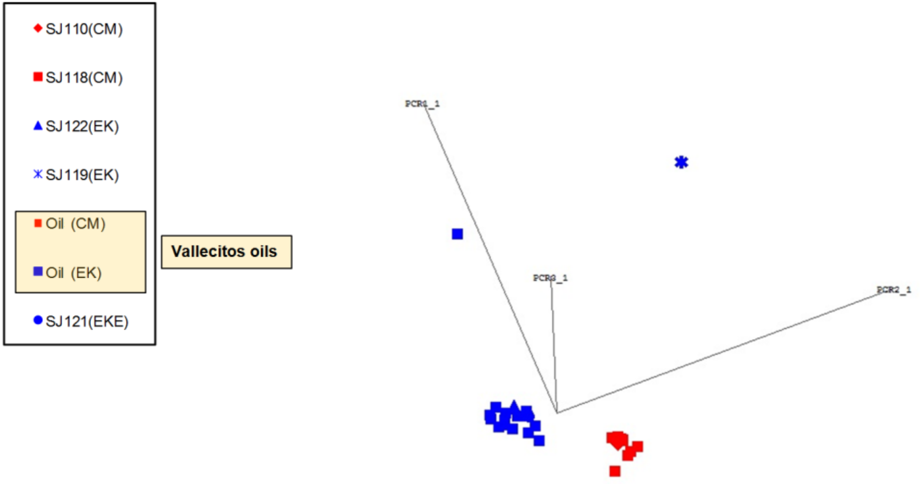


Presenter's notes: Here is a different biomarker to tell the difference between EK and CM in the comparison data set.

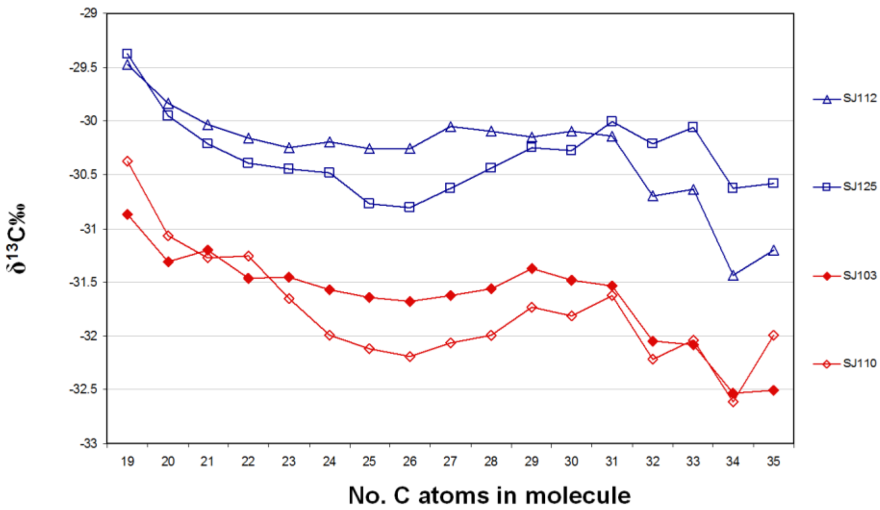


Presenter's notes: We superimposed the Vallectios oils on the same plot and it shows obvious two distinguished groups. Seep 2 is severely biodegreaded and that is why it behaves as an outlier.

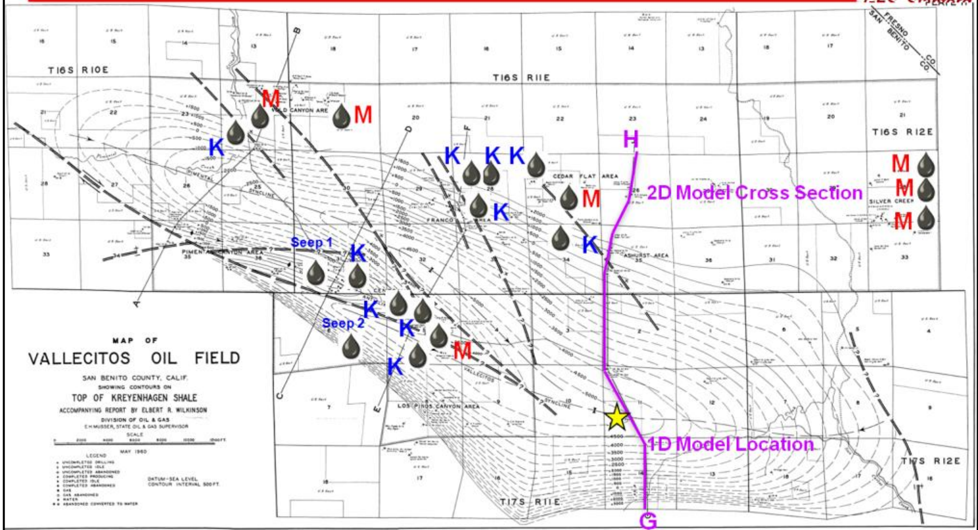
Principal Components Analysis: (PCA) 33 ratios



Compound Specific Isotope Analysis (CSIA): *n*-alkane



Oil family distributions



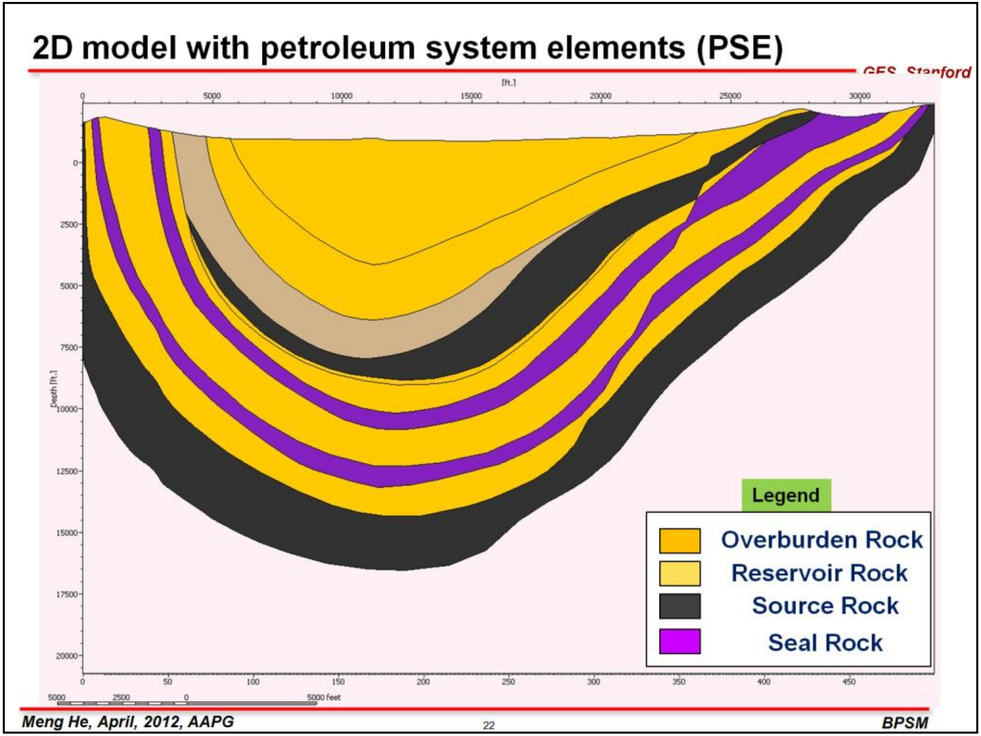
K------Kreyenhagen Oil Type M------Moreno Oil Type

Presenter's notes: Here is the distribution of the oil types. EK oils are located on both sides of the flanks and CM oils are even further away from the central axis of the syncline on the both sides of the flanks.

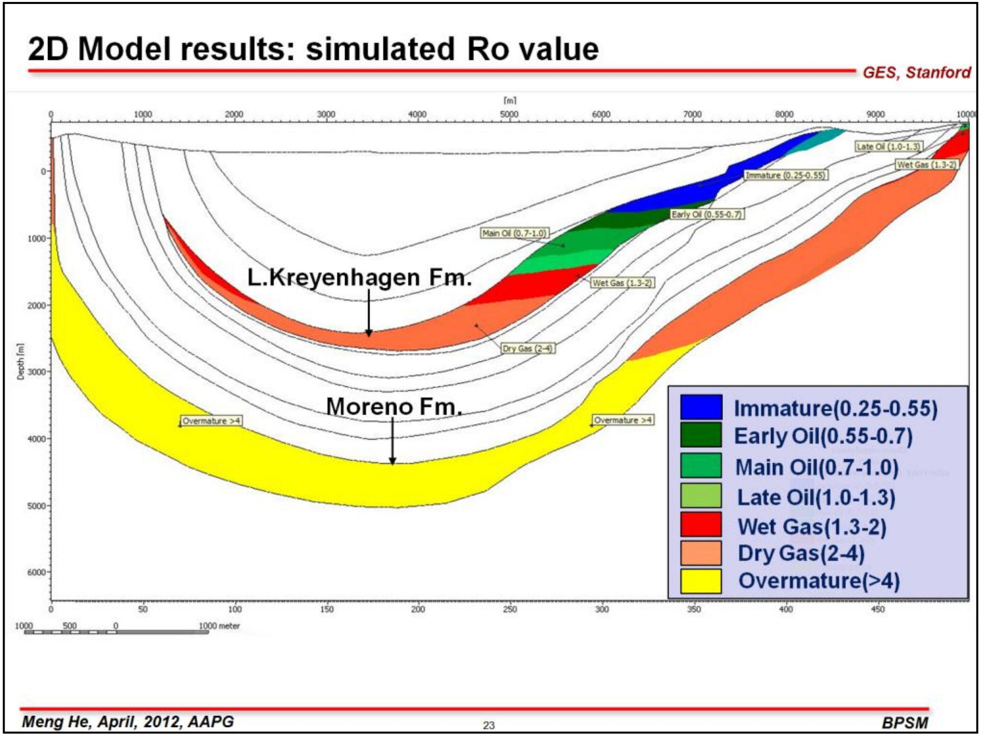
Input modeling parameters

- Two major marine source rocks : 1) Kreyenhagen (TOC= 2.5%, HI=250), 2) Moreno (TOC=2.5%, HI= 169)
- Two major unconformities at 60Ma and 50Ma
- Four minor unconformities at 15Ma, 10Ma, 5Ma and 3Ma and young major folding

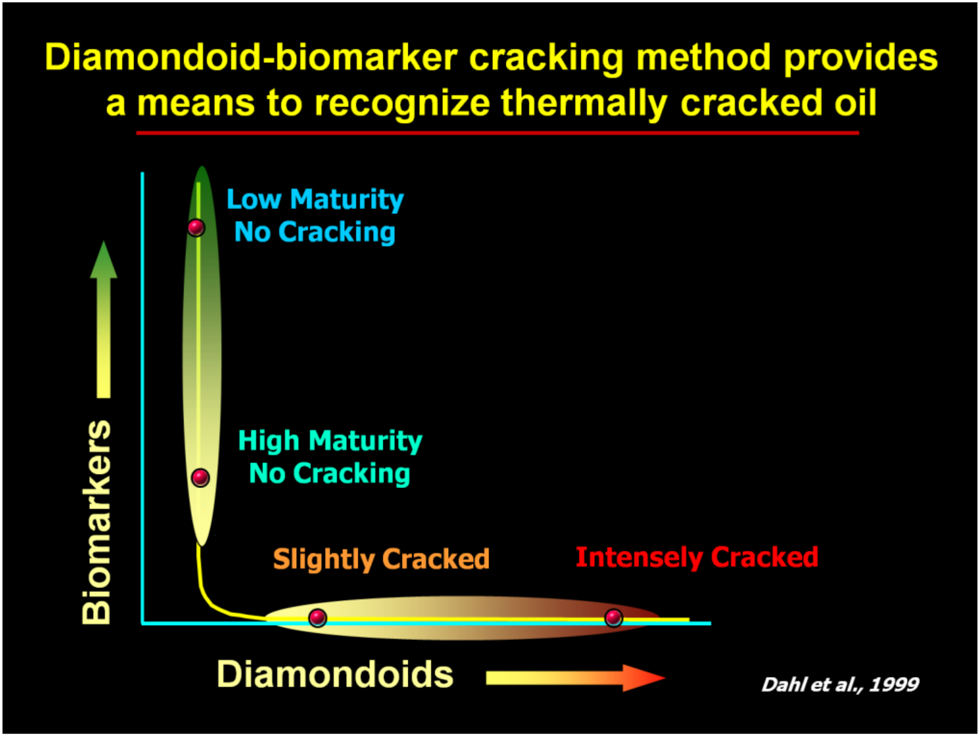
Presenter's notes: Our 2D models involve major erosion, uplift events and the two proposed two marine source rocks. The erosional thickness is the major issue which would impact our model. However, the most uncertain factor here is the HF.



Presenter's notes: Here we are showing the PSE in the 2D. We have 2 source rocks shown by black , three major reservoirs by light yellow and 2 purples shows the seal rock. The dark yellow shows the overburden rock at shallow depth.



Presenter's notes: Here is the result of simulated Ro for hot combo model. In all those three models, we can get the similar results that the Moreno Formation is generating gas in the deepest part and oil on the flanks. Kreyenhagen source is mature at the present day in the deepest part and immature on the flanks.


Diamondoid-biomarker cracking method provides
a means to recognize thermally cracked oil
Low Maturity
No Cracking
High Maturity
No Cracking
Slightly Cracked
Intensely Cracked
Biomarkers
Diamondoids
Dahl et al., 1999

Mixture identification

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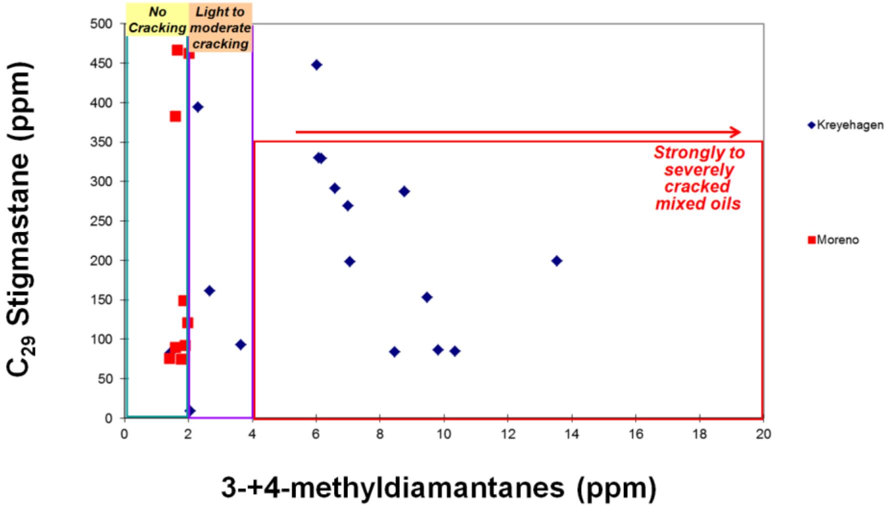

Compound Specific Isotope Analysis (CSIA-D): diamondoids

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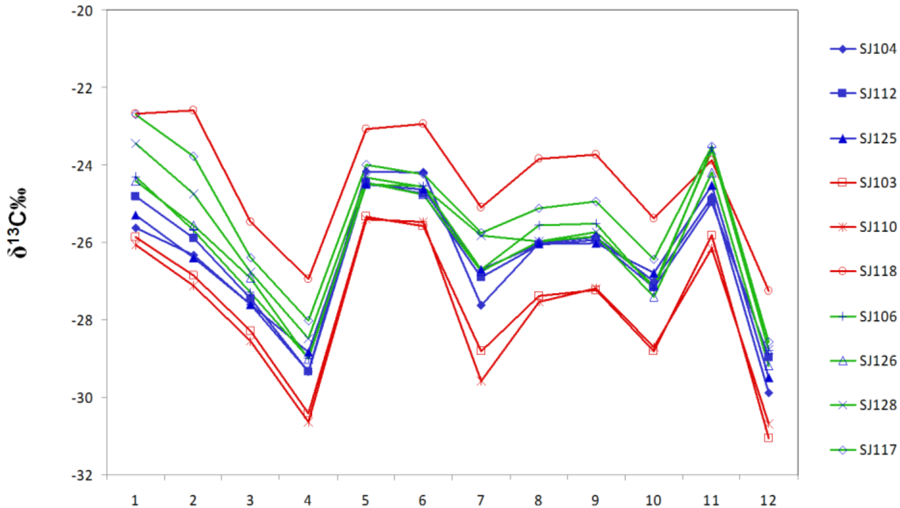

1)Adamantane, 2)1-Methyladamantane, 3)1,3-Dimethyladamantane, 4) 1,3,5-Trimethyladamantane, 5)1,4-Dimethyladamantane(*cis*), 6)1,4-Dimethyladamantane(*trans*), 7) 1,3,6-Trimethyladamantane, 8)1,3,4-Trimethyladamantane(cis), 9)1,3,4-Trimethyladamantane(trans), 10)1,2,5,7-Tetramethyladamantane,11) 3-Dimethyldiamantane, 12) 3,4-Dimethyldiamantane.

Events chart for the Kreyenhagen-Yokut(.) petroleum system

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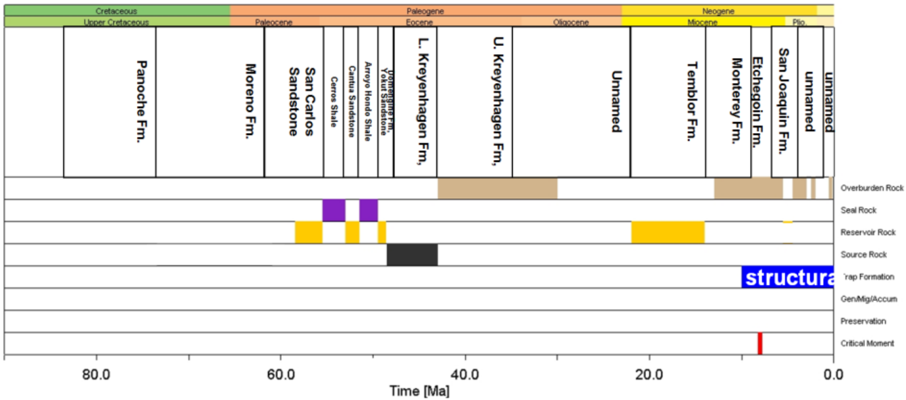
Kreyenhagen-Yokut(.) Petroleum System Events Chart



It shows the time of deposition of the essential elements and processes of the Kreyenhagen-Yokut(.) petroleum system. It has great potential of oil production.

Events chart for the Moreno-San Carlos(.) petroleum system

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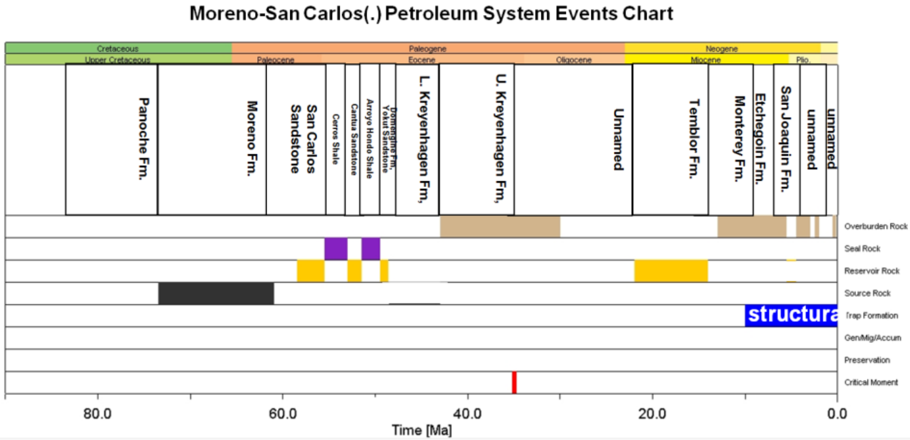

It shows the time of deposition of the essential elements and processes of the Moreno-San Carlos(.) petroleum system. The source rock had great potential of gas production.

Conclusions:

2D model results indicate:

- Moreno Formation is a depleted source rock at present-day. The shallow part of formation has oil window maturity. The early generated oil could not be captured by young traps. It is a major source rock for the gas production.
- Lower Kreyenhagen Formation still have oil generation potential. It has various maturities within the formation.
- Moreno and Kreyenhagen formations were active source rocks in the Vallecitos syncline.

Geochemical results indicate:

- There are two oil types in the Vallecitos syncline: Moreno and Kreyenhagen
- We identified two petroleum systems: 1) Kreyenhagen-Yokut(.) 2) Moreno-San Carlos(.)
- Kreyenhagen-Yokut(.) was charged by oil-window maturity oil and high cracking components from the same Kreyenhagen formation.
- Moreno-San Carlos(.) was charged by oil-window maturity oil from shallow part of the Moreno formation.

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bp
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Statoil
HESS
MOGIA
PetroChina
OXY
BPSM

Future work:

- Calibrate the model (Ro measurements)
- Risk analysis
- Isotope analysis
- Determine the origin of high cracking components in the Kreyenhagen sourced oils to improve understanding of the geological structure of the Vallecitos Syncline (cake layer model or fault effects)
- Distinguish mixed oils, constrain migration pathways and understand reservoir filling history
- Improve understanding of subsurface structure
- Migration analysis (Petrel, Petrocharge express)
- Build 3D forward model of the Kreyenhagen and Moreno formations to predict oil and gas accumulations in the Vallecitos area.

Age of Interval			PetroMod Stratigraphic Unit	Deposition (Ma)		Present Thickness (M)	Erosion/Hiatus (Ma)		Erosion thickness (M)	Lithology	Petroleum System Element
				From	To		From	To			
Cenozoic	Tertiary	Pliocene	Unnamed	0.6	0.2	0	0.2	0	25	Sandstone (typical)	Overburden Rock
			Unnamed	2.5	2	0	2	0.6	381	Shale (typical)	
			San Joaquin Fm.	4.5	3	0	3	2.5	381	Shale (typical)	
		Miocene to Pliocene	Etchegoin Fm.	5.5	4.5	1570.3				Sandstone (typical)	Reservoir Rock
		Miocene	Monterey Fm.	13	5.5	0				Shale(typical)	Overburden Rock
			Temblor Fm.	22	14	701	14	13	152	Sandstone (clay poor)	Reservoir Rock
		Oligocene	Unnamed	37	30	0	30	22	610	Shale(typical)	Overburden Rock
		Eocene	U. Kreyenhagen Fm.	43	37	457				Sandstone(clay rich)	
			L. Kreyenhagen Fm.	48.5	43	366				Shale(organic rich)	Source Rock
			Domengine Fm.	49	48.6	46	48.6	48.5	23	Sandstone (tyical)	Reservoir Rock
		Paleocene to Eocene	Yokut Sandstone	49.5	49	213				Sandstone (clay poor)	
			Arroyo Hondo shale (Lodo Fm.)	51.5	49.5	183				Shale (organic lean)	Seal Rock
			Cantua Sandstone (Lodo Fm.)	53	51.5	427				Sandstone (clay poor)	Reservoir Rock
			Cerros Shale (Lodo Fm.)	55.5	53	107				Shale (organic lean)	Seal Rock
			San Carlos Sandstone (Lodo Fm.)	58.5	55.5	274				Sandstone (clay poor)	Reservoir Rock
Mosozoic	Cretaceous to Paleocene		Moreno Fm.	73.5	61	594	61	58.5	100	Shale (organic rich)	Source Rock
			Panoche Fm.	83.5	73.5	1000				Shale (organic lean)	Underburden Rock

Different 1D model scenarios

Active strike-slip, shallow thin-skinned(crustal) extension only: 60 mW/m^2

Forearc basin unrelated to arc magmatism: 35 mW/m^2

(Allen and Allen, 2005)

Age (Ma)	Paleowater depth (m)	Age (Ma)	SWIT (sediment-water interface temperature)	Model 1		Model 2		Model 3	
				Age (Ma)	HF(heat flow, mW/m^2)	Age (Ma)	HF(heat flow, mW/m^2)	Age (Ma)	HF(heat flow, mW/m^2)
0	-150	0	17.3	0	68	0	68	0	68
4.5	-100	4.5	16.3	5	**70**	5	66.5	5	**70**
5.5	-80	5.5	16.33	10	**80**	10	60	10	**80**
16	-50	16	20.4	15	**85**	15	55	15	**85**
18	600	18	5.69	20	**75**	20	45	20	**65**
37	1000	37	24.47	25	60.6	25	30	25	40
43	600	43	12.7	30	59	30	30	30	30
48.5	200	48.5	19.48	35	57.5	35	30	35	30
49	1000	49	24.6	40	56	40	30	40	30
49.5	1000	49.5	13.32	45	54.5	45	30	45	30
51.5	1000	51.5	13.63	50	53	50	30	50	30
53	1000	53	13.88	55	51.5	55	30	55	30
55.5	1000	55.5	14.17	60	50	60	30	60	30
58.5	1000	58.5	24.13	65	48.5	65	30	65	30
73.5	1000	73.5	14.82	73.5	46	73.5	30	73.5	30

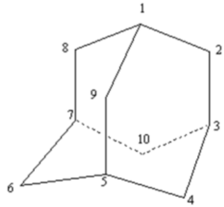
Hot Cold Combination

Three HF scenarios were proposed due to northward progression of the Mendocino Triple Junction and refrigeration of subducted slab below the syncline.

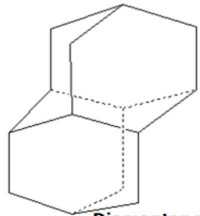
Age (Ma)	Paleowater depth (m)	Age (Ma)	SWIT (sediment-water interface temperature)	Model		Depth (m)	Ro%	Tmax(°C)	Ro% (converted from Tmax)
				Age (Ma)	HF (Heat flow, Mw/m²)				
0	-150	0	17.3	0	68	1100		428	0.54
4.5	-100	4.5	16.3	9	**145**	1119	0.54	426	0.51
5.5	-80	5.5	16.33	14	**155**	1228		427	0.53
16	-50	16	20.4	16	**155**	1301	0.59		
18	600	18	5.69	18	**160**	1347		432	0.62
37	1000	37	24.47	25	75	1393		431	0.6
43	600	43	12.7	30	70	1430		430	0.58
48.5	200	48.5	19.48	35	65	1503	0.61		
49	1000	49	24.6	40	60	1512		431	0.6
49.5	1000	49.5	13.32	45	54.5	1539		432	0.62
51.5	1000	51.5	13.63	50	53	1594		434	0.65
53	1000	53	13.88	55	51.5	1646		432	0.62
55.5	1000	55.5	14.17	60	50	1673		433	0.63
58.5	1000	58.5	24.13	65	48.5				
73.5	1000	73.5	14.82	73.5	46				

What are the Diamondoids?

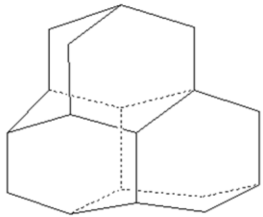
- More thermally stable
- Resemble diamond in the carbon cage structure
- Concentrated due to oil cracking



Adamantane

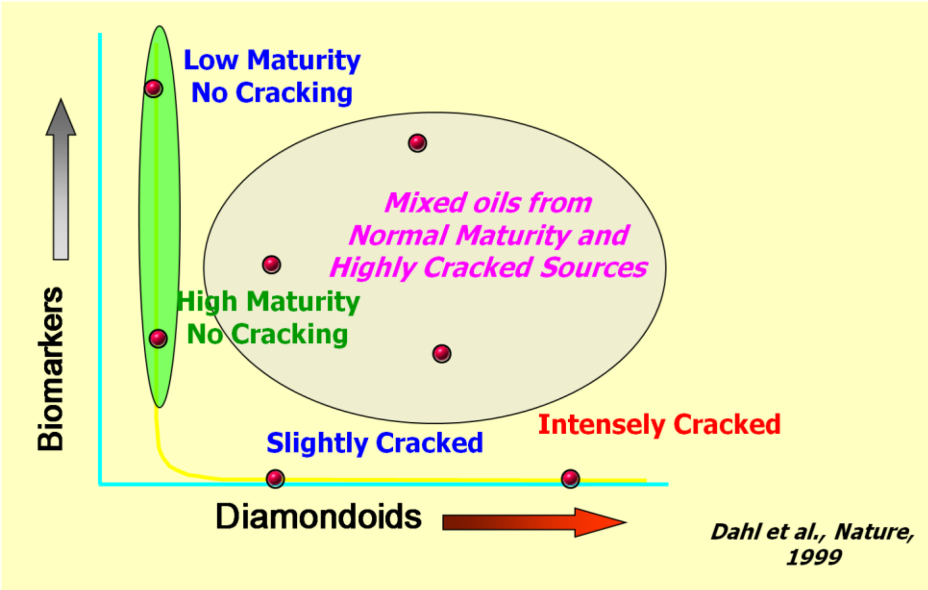


Diamantane

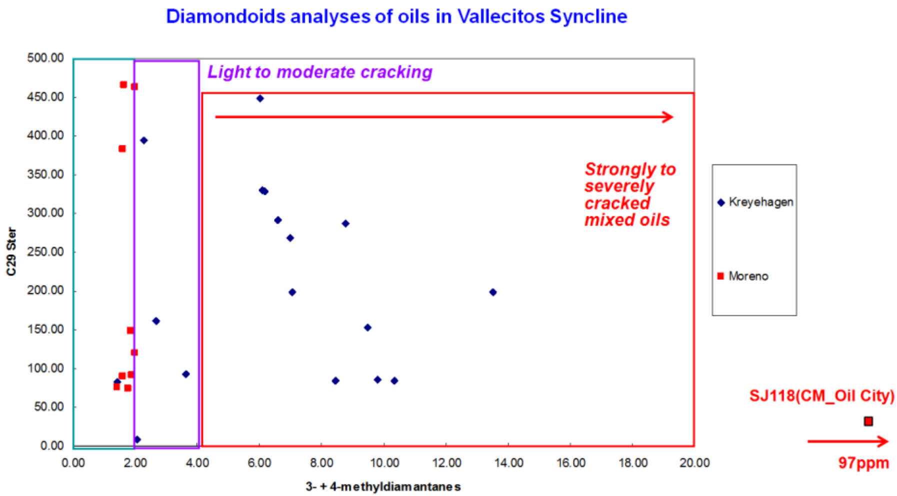


Triamantane

Recognition of oil-cracking and mixed oils:

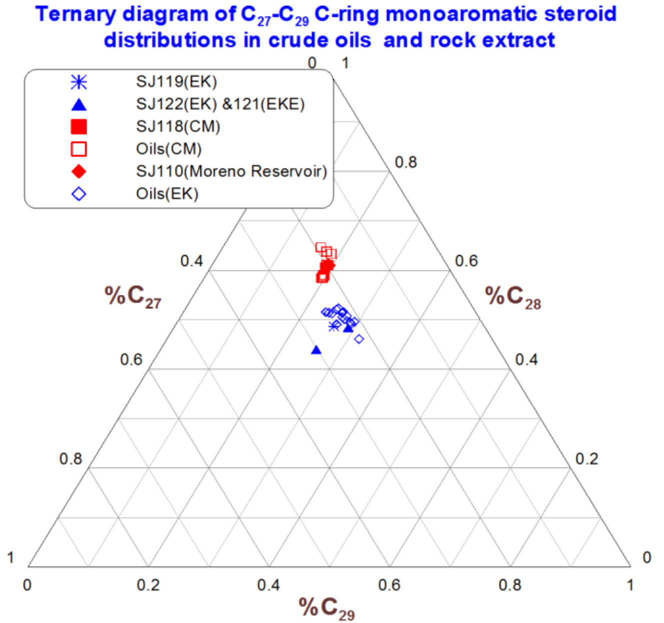


Recognition of oil-cracking and mixed oils

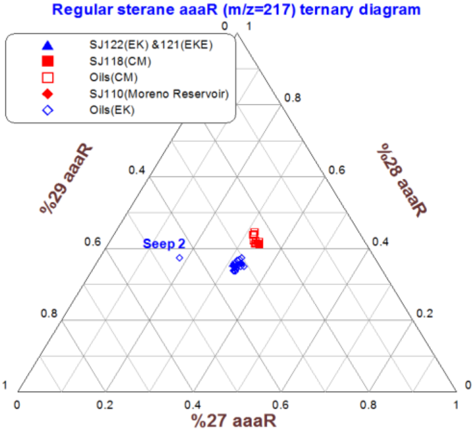


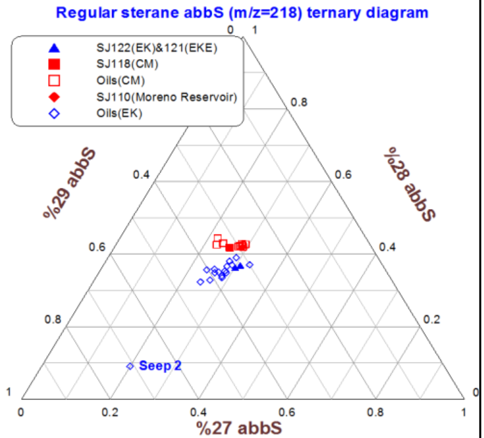
MA-steroids show two oil groups

GES, Stanford



Steranes show two oil groups





After California Division of Oil and Gas (CDOG), 1982

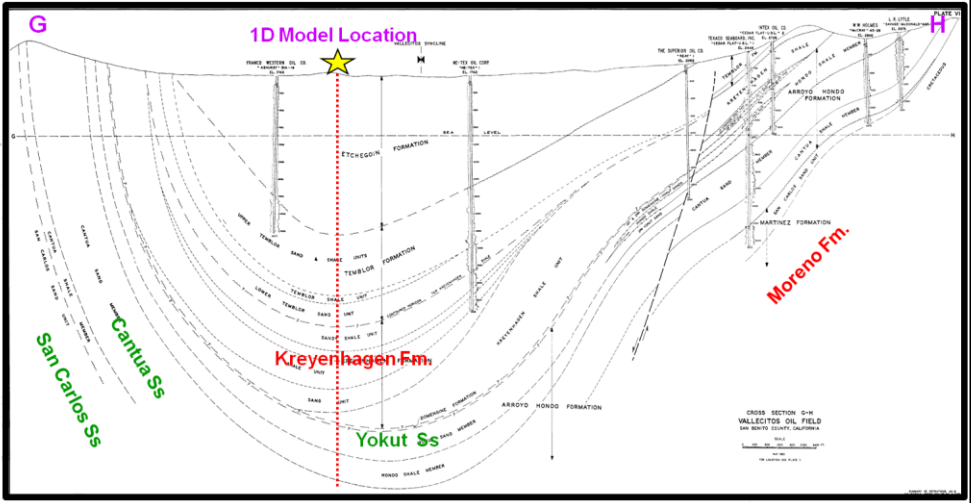
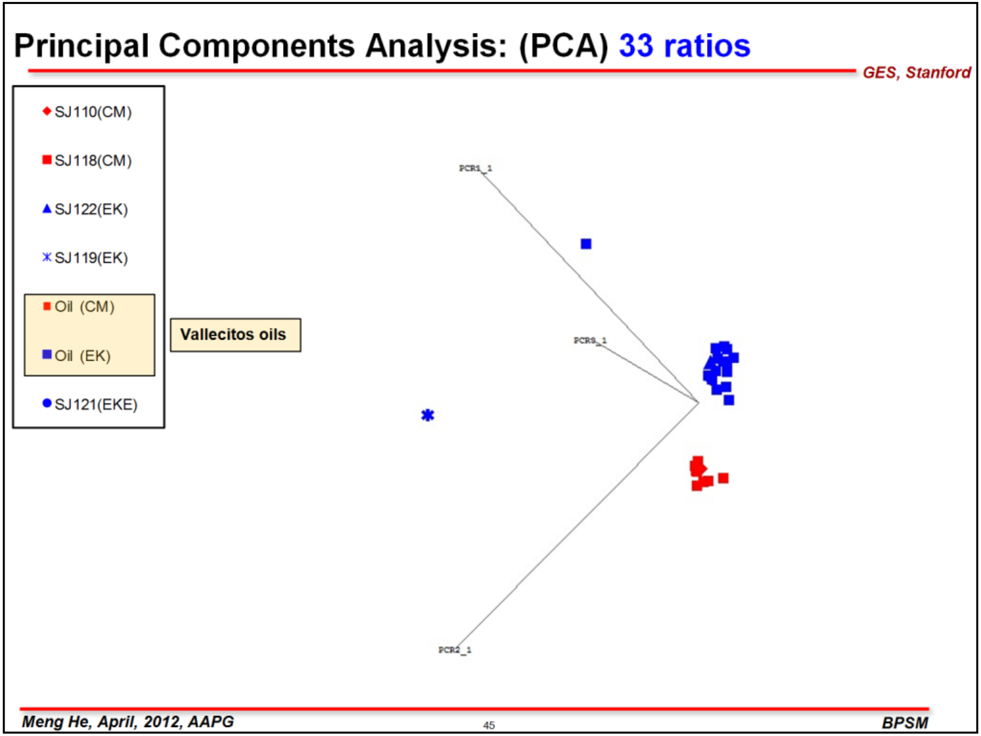
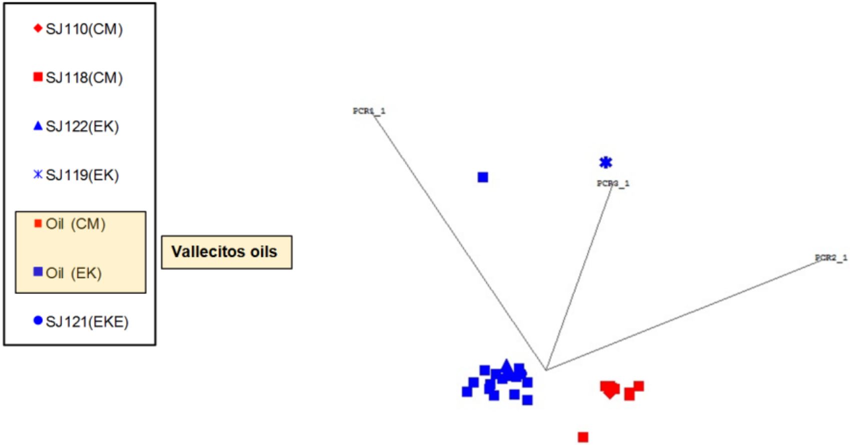


Figure 6. Geological profile along the line GH (Fig. 1a) in the Vallecitos syncline.



Presenter's notes: PCA is a statistic tool to get rid of the redundancy from each parameter to better express the genetic relationship behind the data set. It gives three major components which tell the most differences among the data. Here you can clearly see the two distinguished clusters. The two outliers are 2 seeps; one is from Vallecitos (Seep 2) the other is the Big Caynon seep which is EK source from the comparison data.

Principal Components Analysis: (PCA) 33 ratios



Principal Components Analysis: (PCA) 33 ratios

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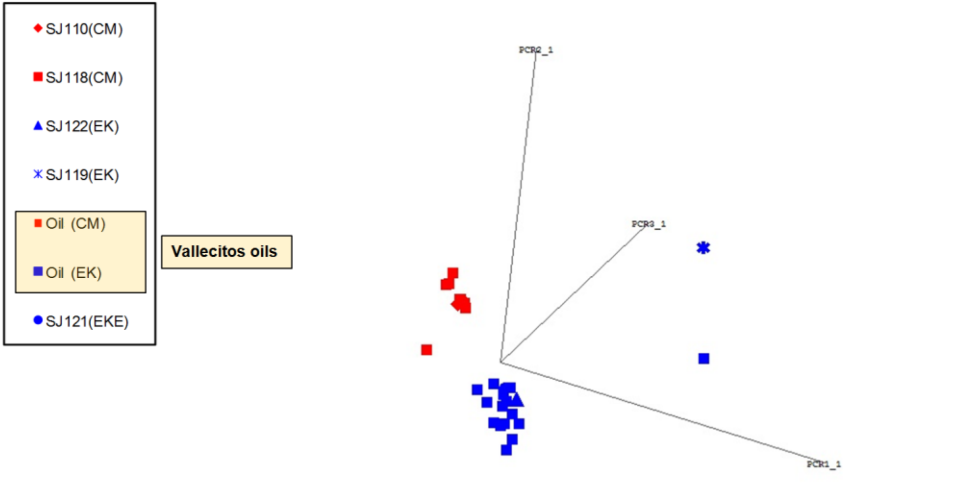
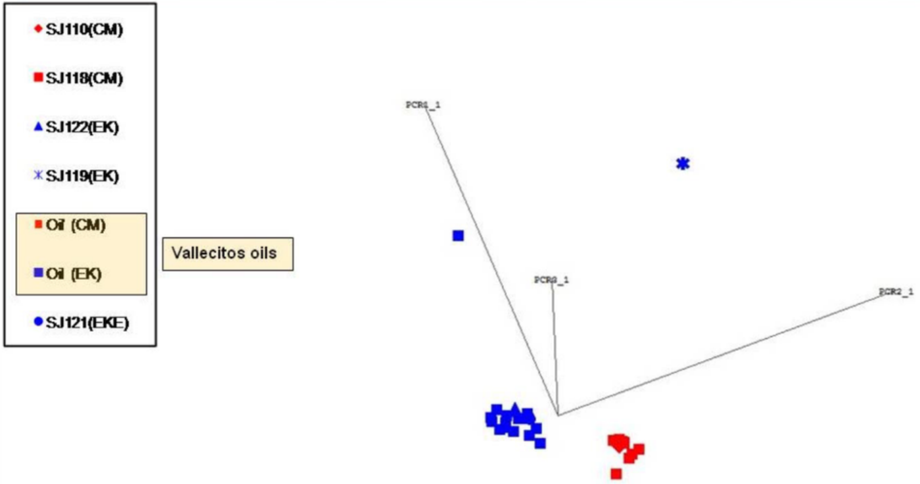


Principal Components Analysis: (PCA) 33 ratios



Principal Components Analysis: (PCA) 33 ratios

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