What is Next for the "Mature" Sacramento Basin? The West Side Story, A Brief Look into the Lower Cretaceous and Upper Jurassic Rock*

Robert Sterling[1]

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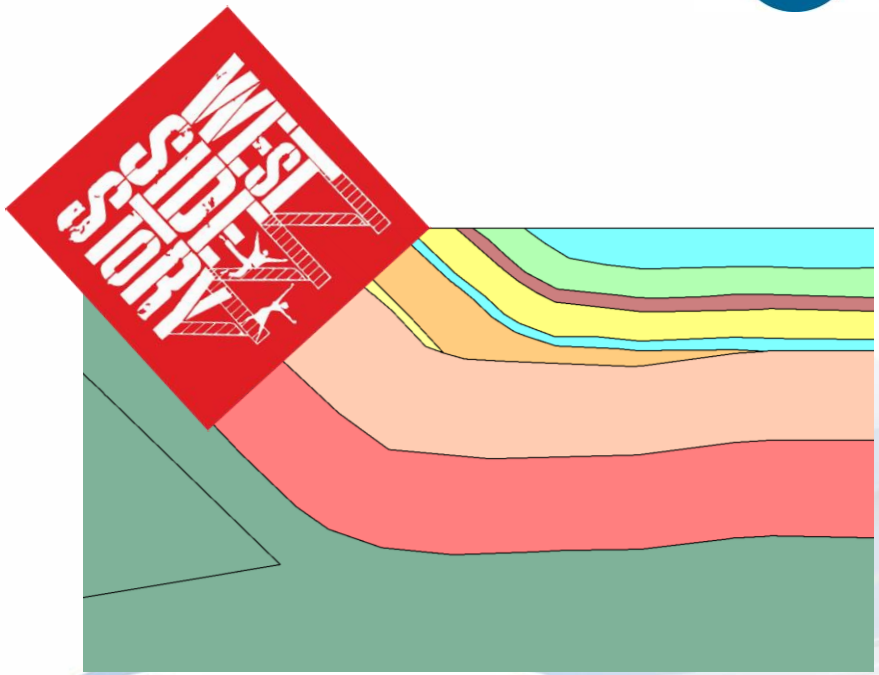
Abstract

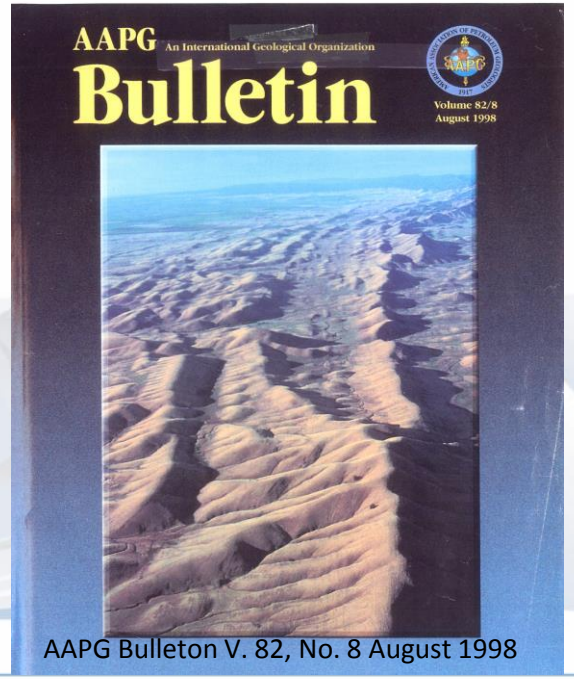
The Sacramento Basin has seen little in the way of exploration for the last number of years. Traditional productive areas have been heavily exploited through the use of 2D and 3D seismic such that smaller and smaller targets were successfully drilled and produced. An effort to look for another possible exploration province was undertaken beginning in the 1990's by this author. The Lower Cretaceous and Upper Jurassic sediments that form the outcrop belt along the western side of the Sacramento Basin have had a disjointed drilling history filled with shallow wells, heavy mud, and no commercial results.

The Lodoga and Stoney Creek formations represent the earliest deposition into the forearc basin formed by the subduction of the Farallon Plate underneath the North American Plate during the Late Jurassic and early Cretaceous periods. Middle to Late Cretaceous sediments were deposited further east as the early basin was filled. Approximately 45,000 feet of measured section has been observed in the outcrop belt. Sediments are composed of marine shales and sands. The sands were deposited as deep water turbidites and range from fine grained sands interbedded with silty shales to thick conglomerates. Sediments tend to be high in lithic content due to the provenance of early Sierra Nevadan volcanic rocks. Recent drilling by various operators have tested several concepts for these rocks with confidential results. The most recent well with data publicly available is the CRC Tulainyo #1 in section 7 T18N R4W which was abandoned in January 2015 after encountering mechanical difficulties. This well encountered interesting indications of gas while drilling and logs indicate saturation of gas in the sands, though the area is very structurally complicated.

What is next for the “Mature” Sacramento Basin? The West Side Story, A brief look into the Lower Cretaceous and Upper Jurassic Sediments

Robert Sterling
Confluence Resources LP



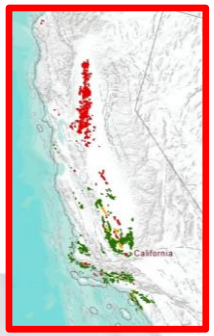


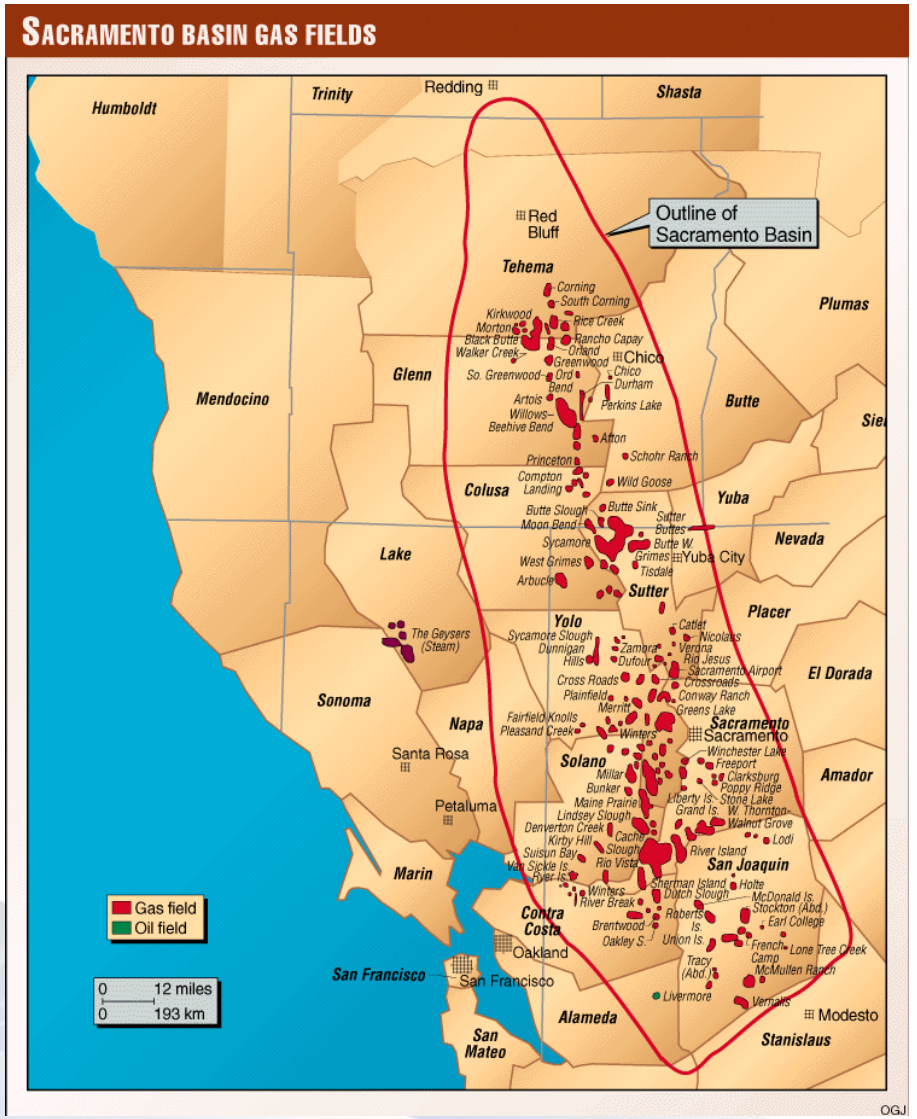
AAPG Bulleton V. 82, No. 8 August 1998

Sacramento Basin Exploration has all but ceased in the last few years

- First gas discovered in 1936
- Several episodes of exploration
  - 1976-84 – “Bright” Spot
  - 1985-93 – AVO
  - 1994-present – 3D Seismic

- All activity focused on Upper Cretaceous to Miocene aged rocks in the “basin proper”
- Lower Cretaceous and Upper Jurassic sediments have been lightly explored through time
  - Recent exploration activity focused on older rocks
- Analogues exist for these types of prospects
  - Pinedale Field, WY
  - Jonah Field, WY
  - Piceance Basin, CO
  - Anschutz Ranch, UT





Stratigraphy for Lower Cretaceous

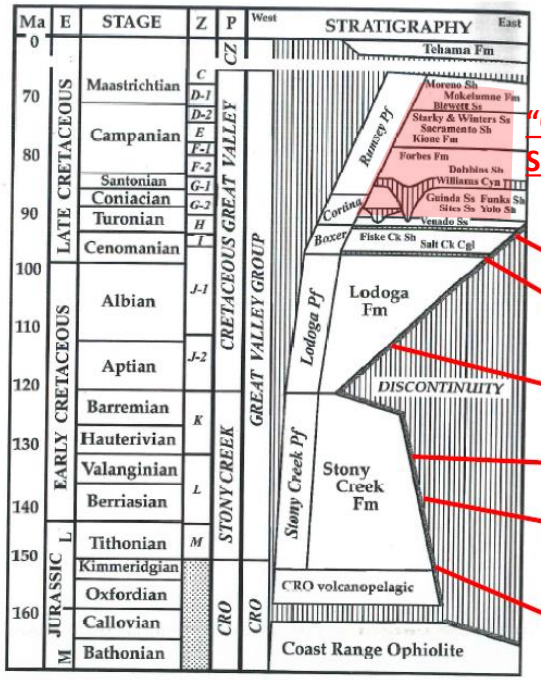
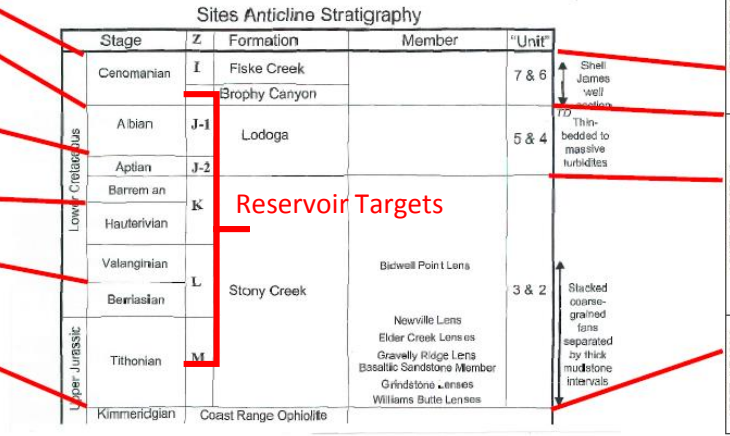
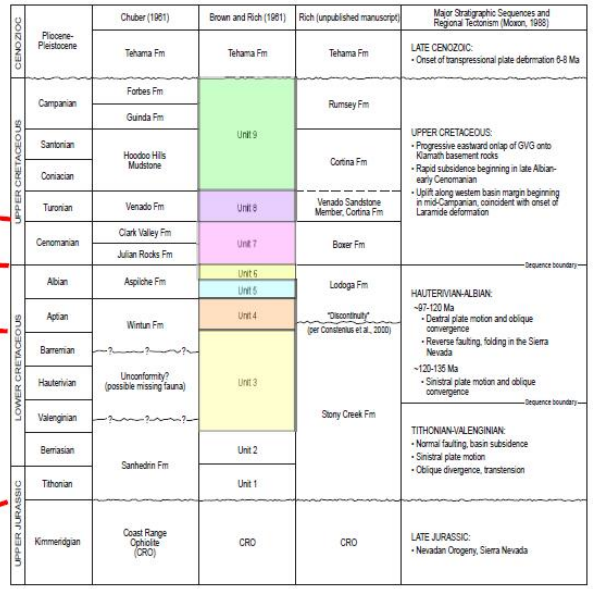


Figure 4. Chronostratigraphy of the Great Valley homocline, northwest Sacramento Valley, highlighting stratigraphic age relations associated with the Lower Cretaceous discontinuity imaged on seismic data, penetrated by wells, and seen on regional maps and satellite imagery of outcrops. Note that no major unconformities punctuate the Great Valley Group with the exception of a submarine unconformity related to incision of Williams Canyon (Williams et al., 1998). Abbreviations: CRO—Coast Range ophiolite; CZ—Cenozoic rock package; E—epoch; P—rock packages defined in Figures 8 and 9; Pf—petrofacies of Ingersoll (1983); Z—benthic foraminiferal zonation (Almgren, 1986). Sources for stratigraphic column: Bertucci (1983), Ingersoll (1979), Robertson (1990), Gradstein et al. (1994), Dickinson et al. (1996), Williams (1997).

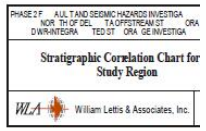
"Classic" Productive Formations in Sacramento Basin



Reservoir Targets



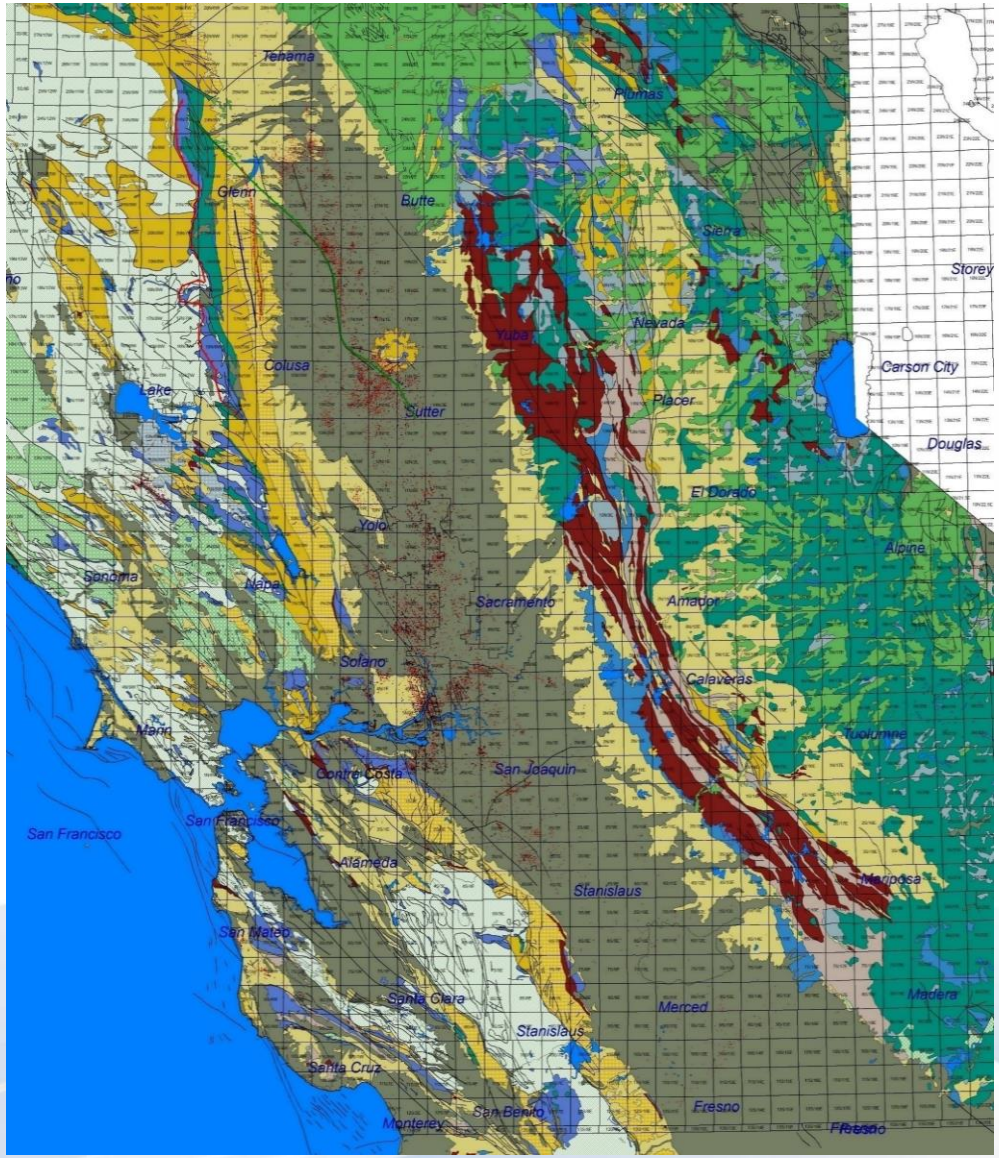
Correlation of all Known Stratigraphic Nomenclature



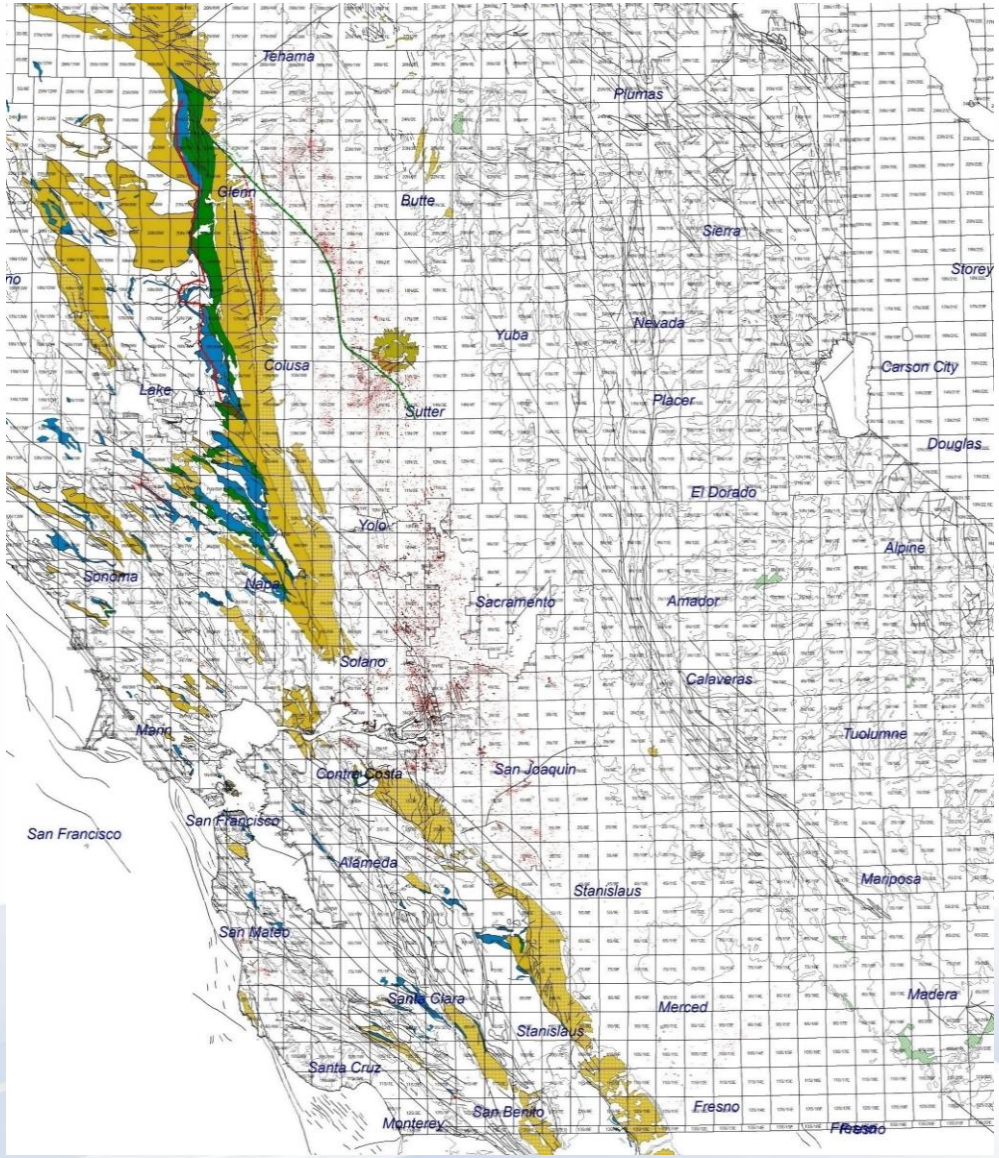
There have been numerous names assigned to the older rocks in the basin. Main Target for Exploration are

- **Lodoga Formation – Lower Cretaceous**
- **Stony Creek Formation – L K/ Up Jurassic**

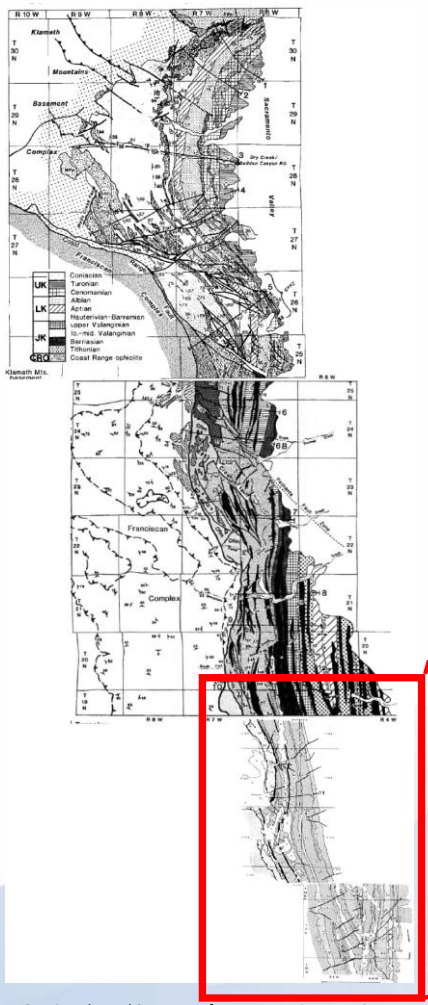
Northern California Surface Geologic Map

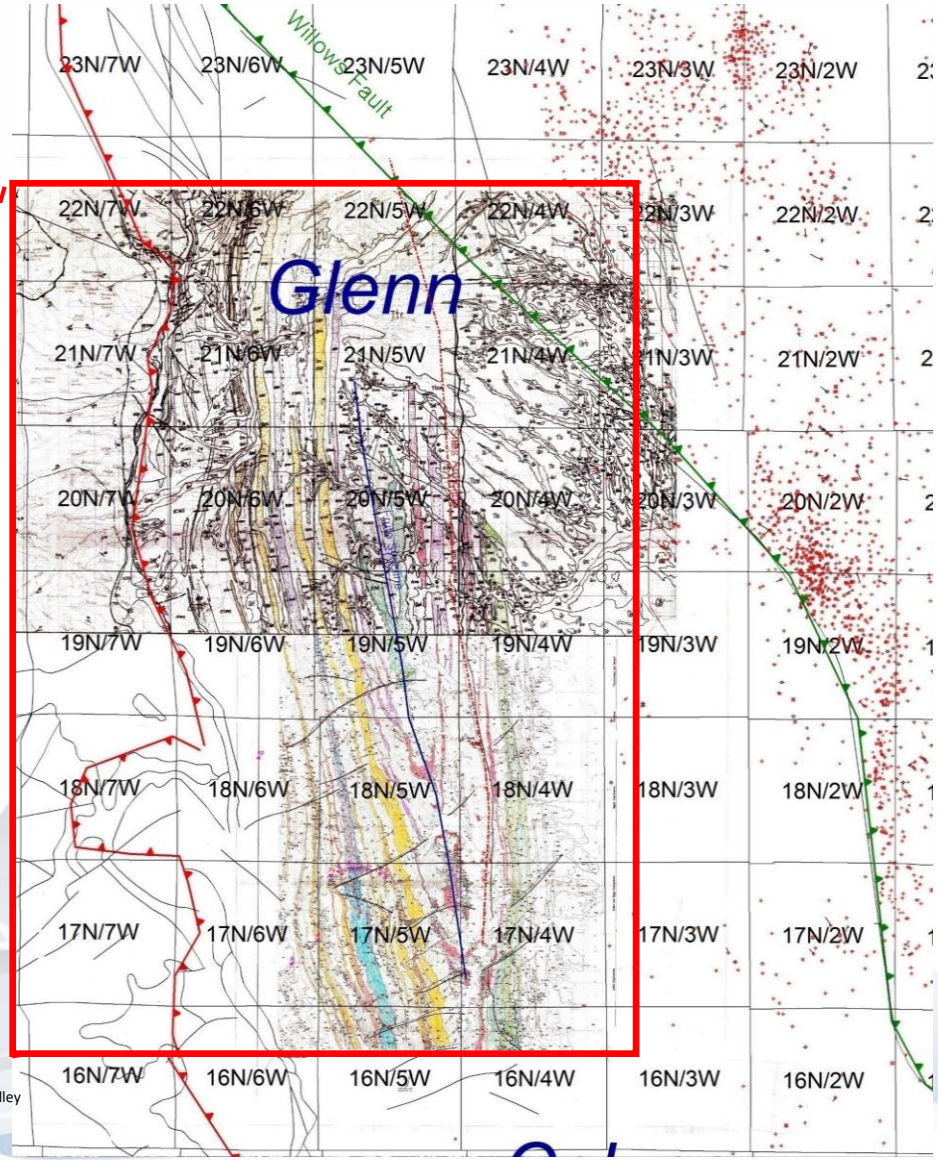


Lower Cretaceous and Upper Jurassic Sediments



Surface Geologic Mapping has been extensively done on the outcrop belt

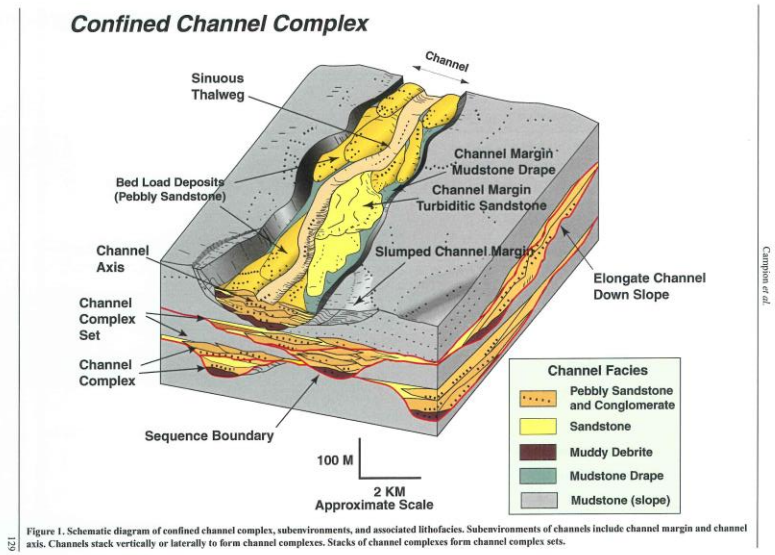




From: Moxon, Ian; Stratigraphy and Structure of Upper Jurassic-Lower Cretaceous Strata, Sacramento Valley Symposium and Guidebood, 1990, SEPM

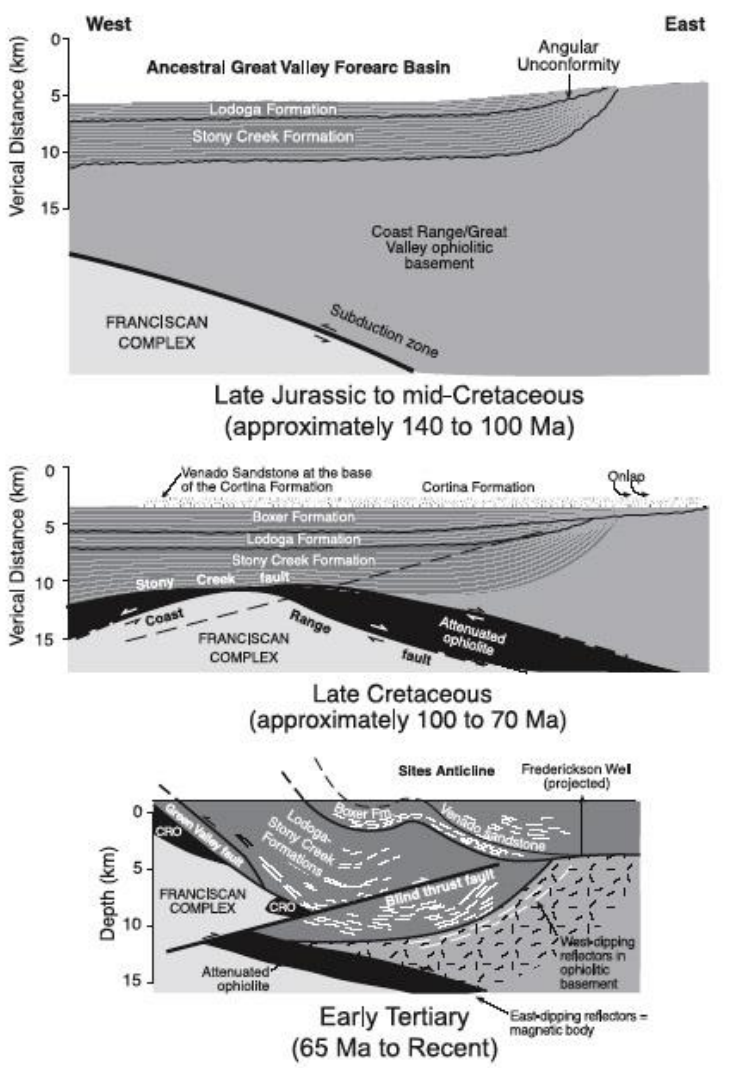
Mapping from USGS 1960, 1992 and Sterling 2001, 2003 and 2010

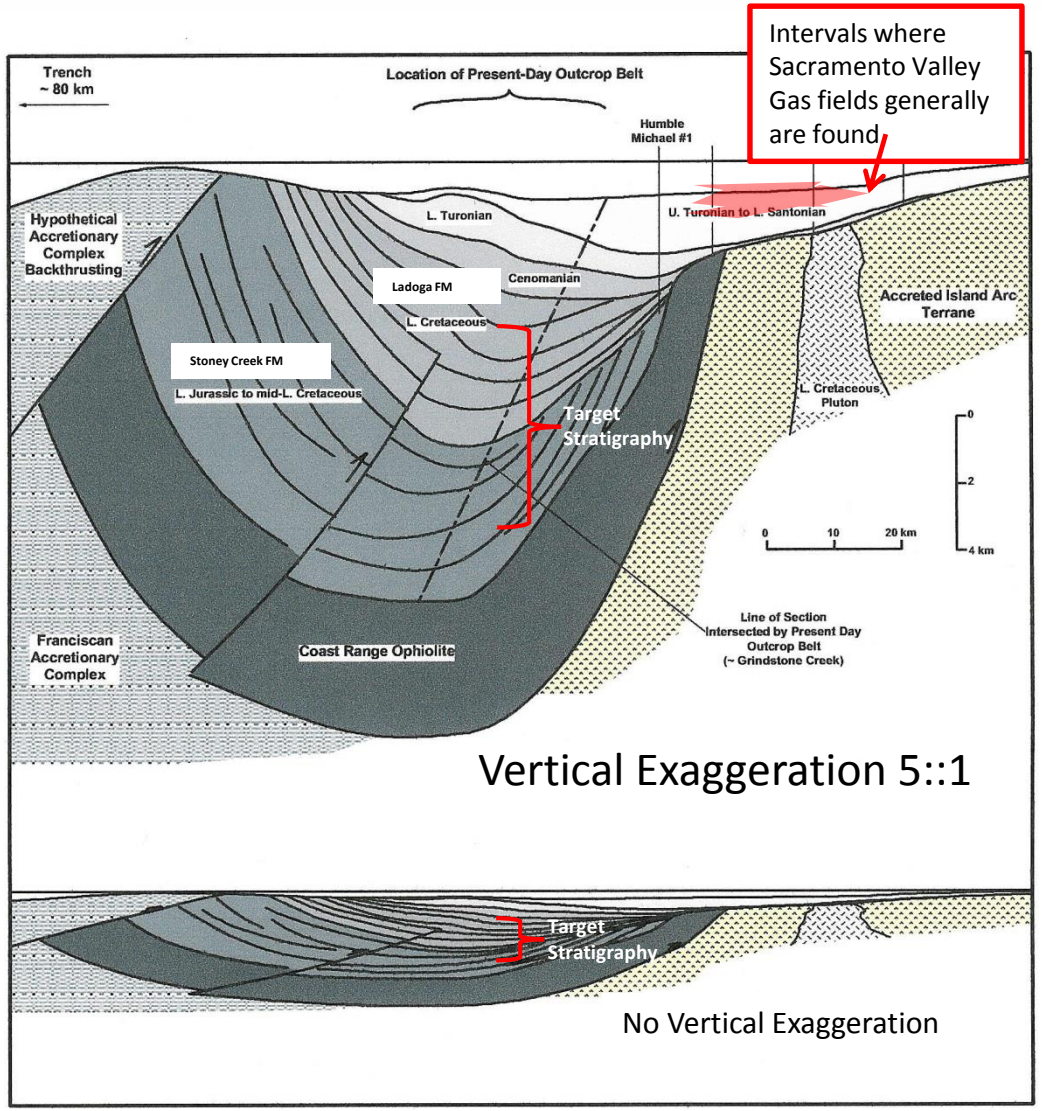
Early Cretaceous – Aptian – 125 Ma
J2 Lower Lodoga FM – Unit 4 (*Brown & Rich, 1961*)



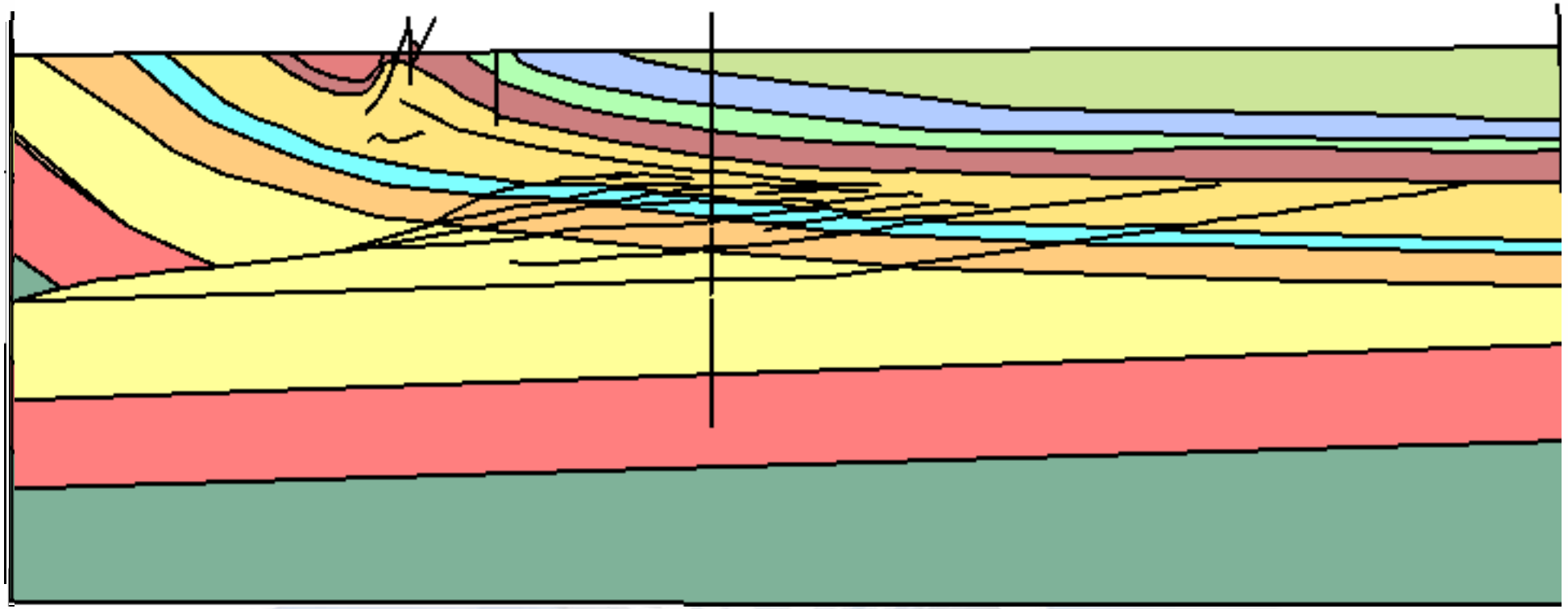
Turbidites deposited in forearc basin during UJ/LK tended to be focused at and parallel to the base of the slope

Regional Stratigraphic and Structural History





Structural History Model for the West Side in the area of the Sites Anticline

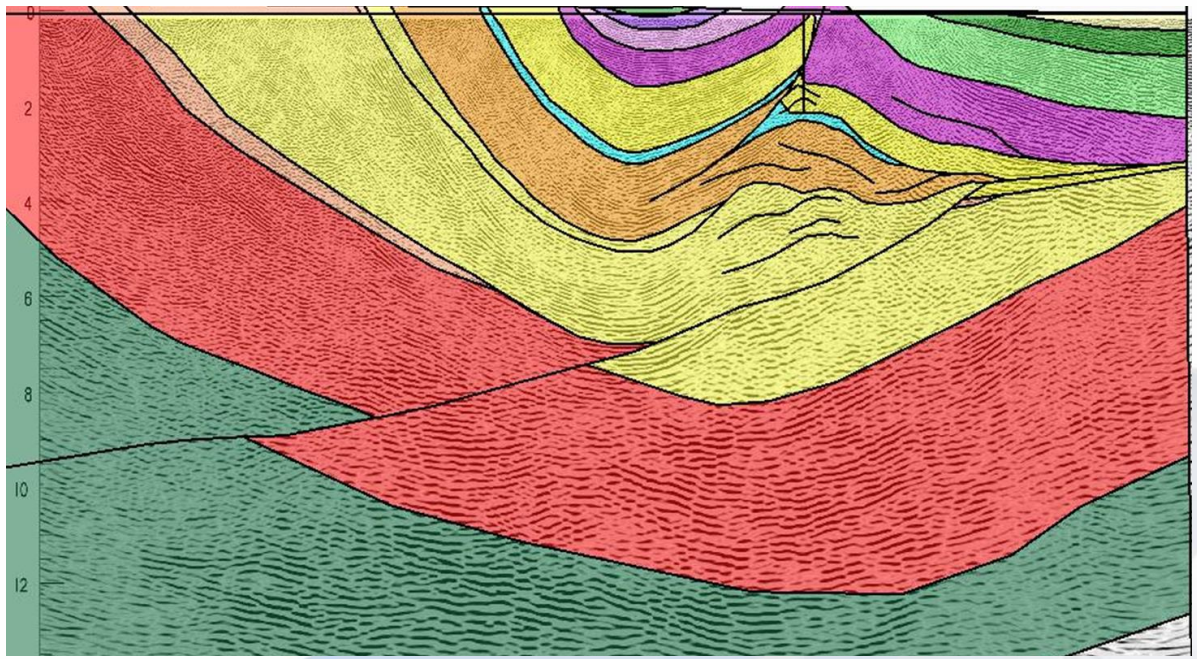


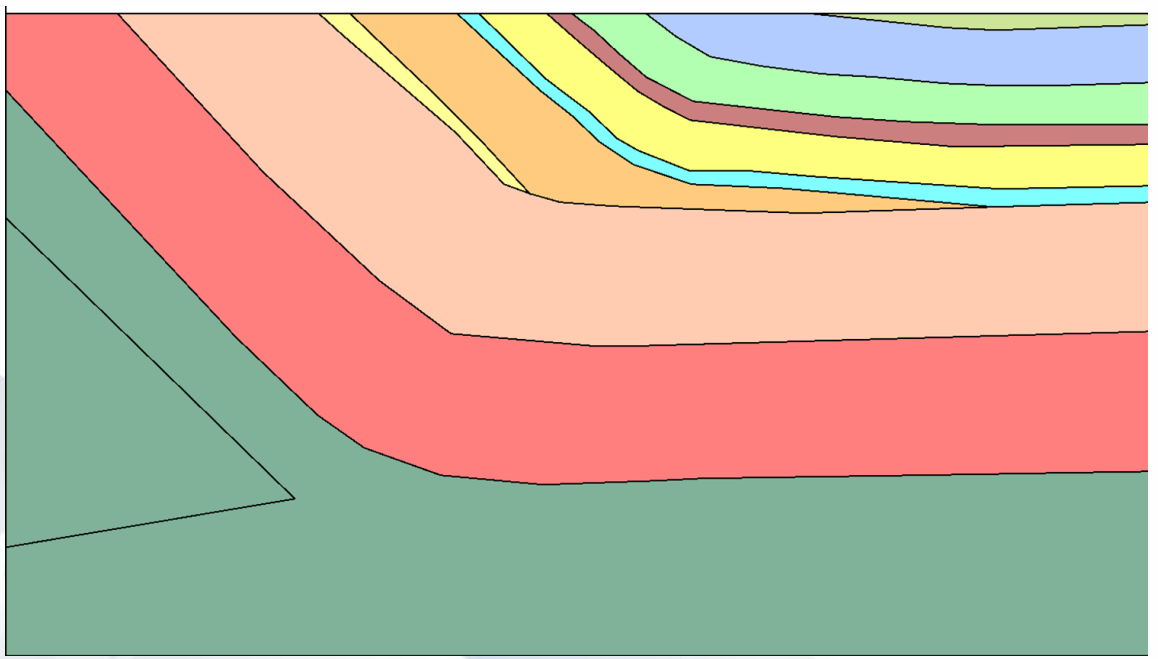
Sterling and Kluth 2009 internal Cirque Study

Two major structural styles present in the Lodoga/Stony Creek section on the west side of the basin

Sites Anticline represents a shorted section in the uplift that resulted in a large, faulted anticline that is 20 miles long along a North-South axis

The majority of the western outcrop belt has a simpler structural style where the beds have been upturned by the thrusting of the Coast Range Ophiolite of the Franciscan Formation

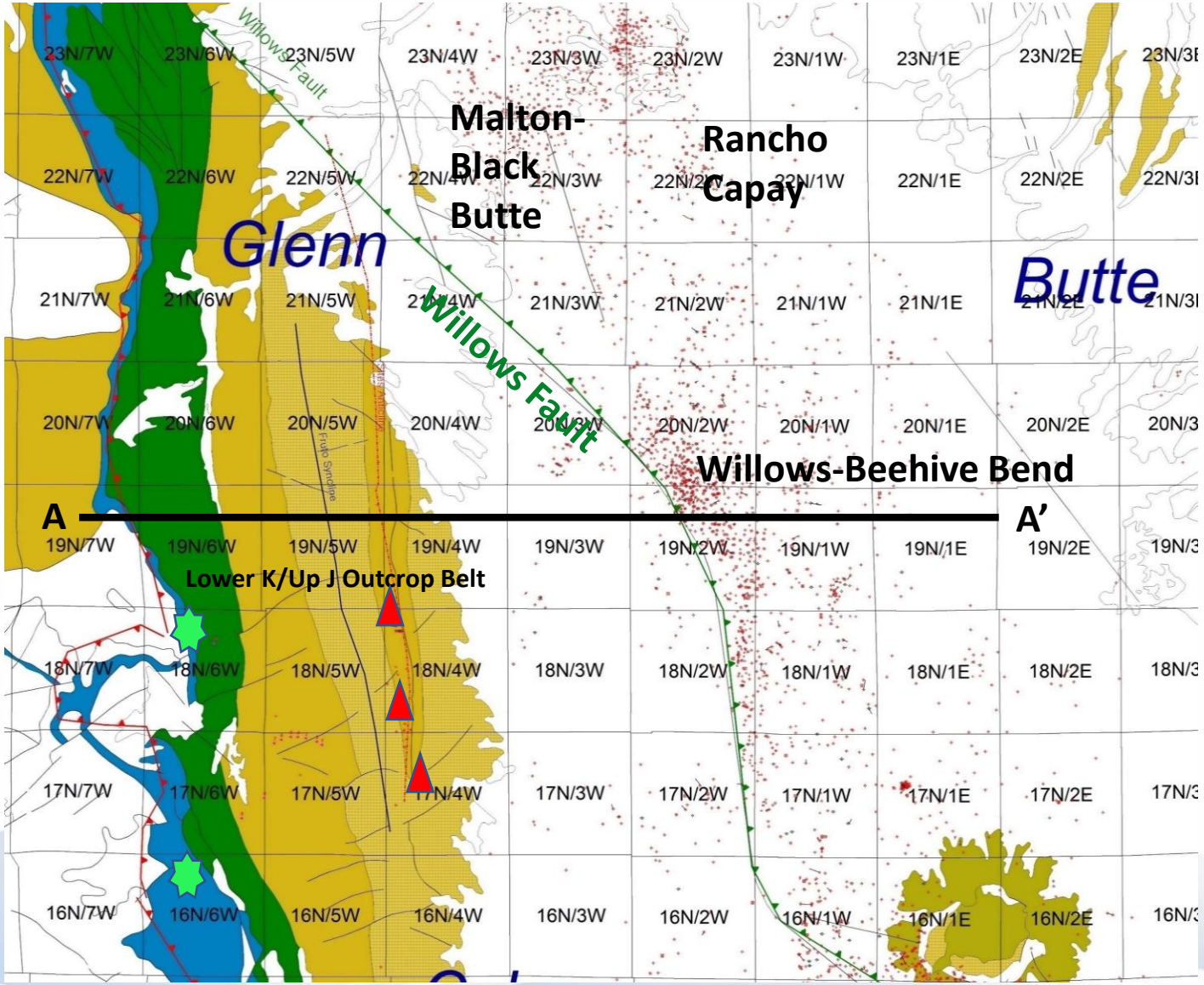




EW section located along Shell Seismic line #1

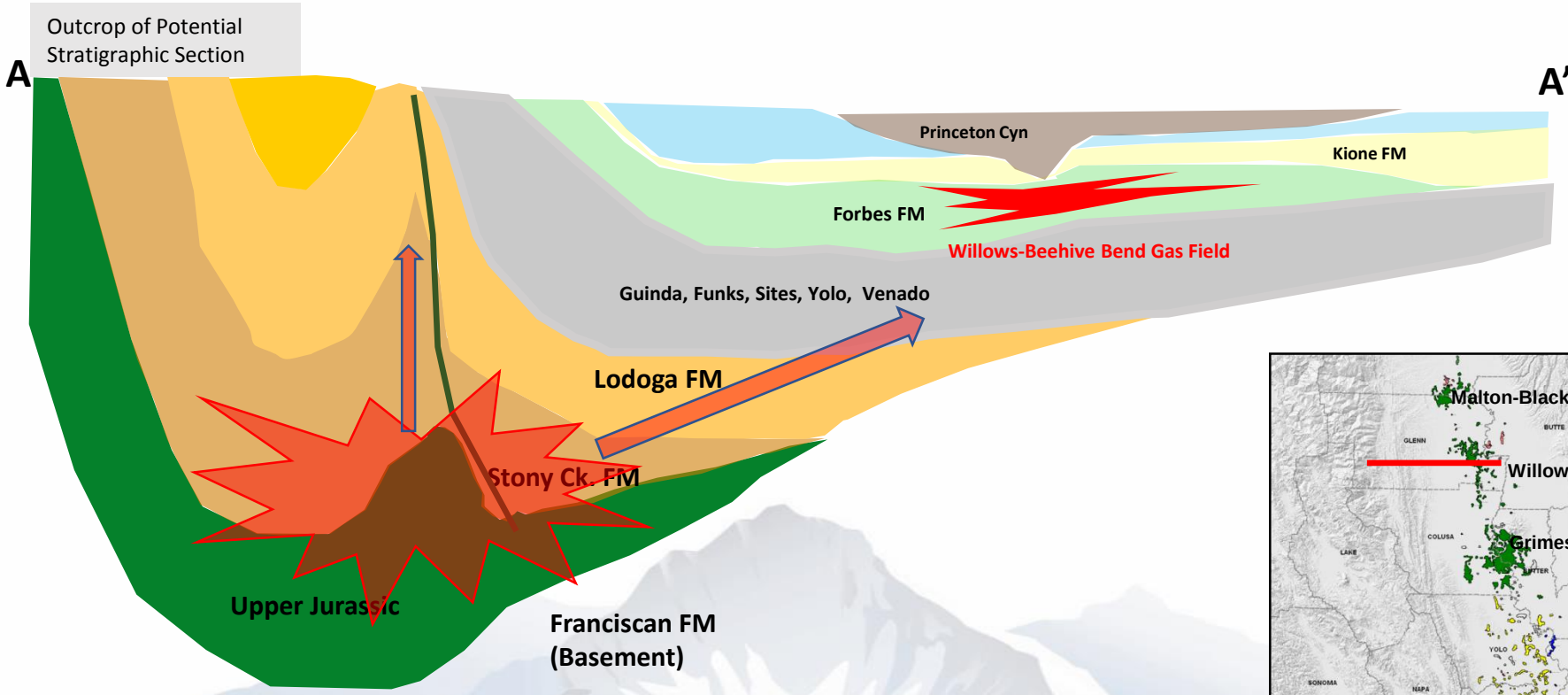
Sterling and Kluth 2009 internal Cirque Study

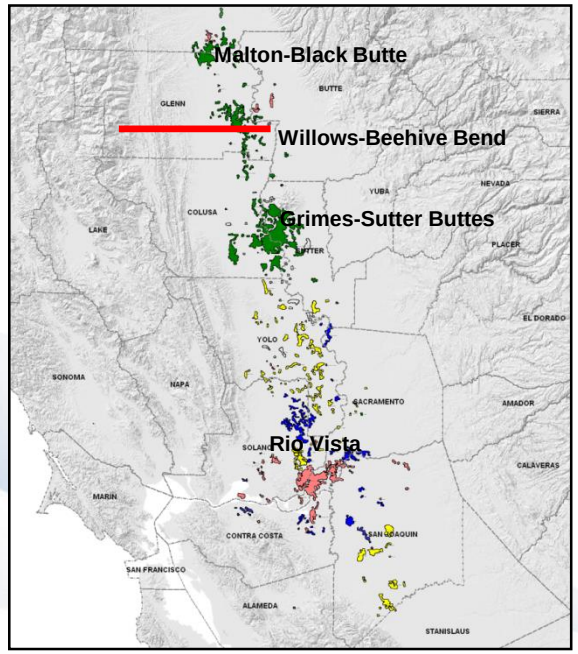
Historical Producing Trends are located east of the Willows Fault



Relationship of Historical Producing Trends to Older Sediments

Sacramento Basin accumulations have been associated with basin centered gas





Gas for most of this portion of the basin is sourced in these deeper, older sediments

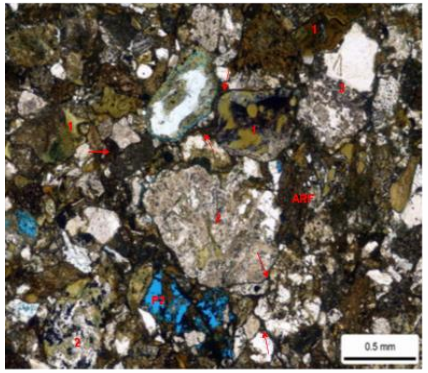
- **Forbes is generally thermally immature**
- **BTU decreases in fields to the east further from source with dilution by Nitrogen from granitic basement**

Lodoga Formation Rock Parameters

- Provenance includes both proto-Sierran Volcanics and Sierra Nevada granitics
- Lithic components but younger rocks become more quartz rich
- Diagenetically immature
  - No zeolites
  - Smectite dominant clay

Company: Cirque Resources
Location: Sacramento Basin, CA
Depth (ft): Outcrop
Sample ID: 5-3A

A



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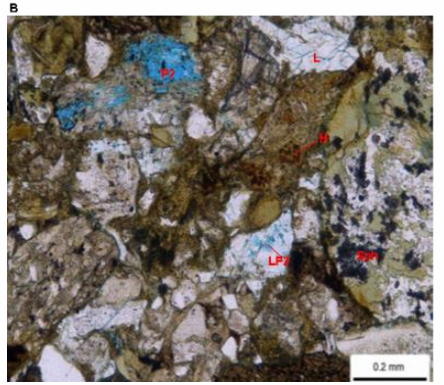
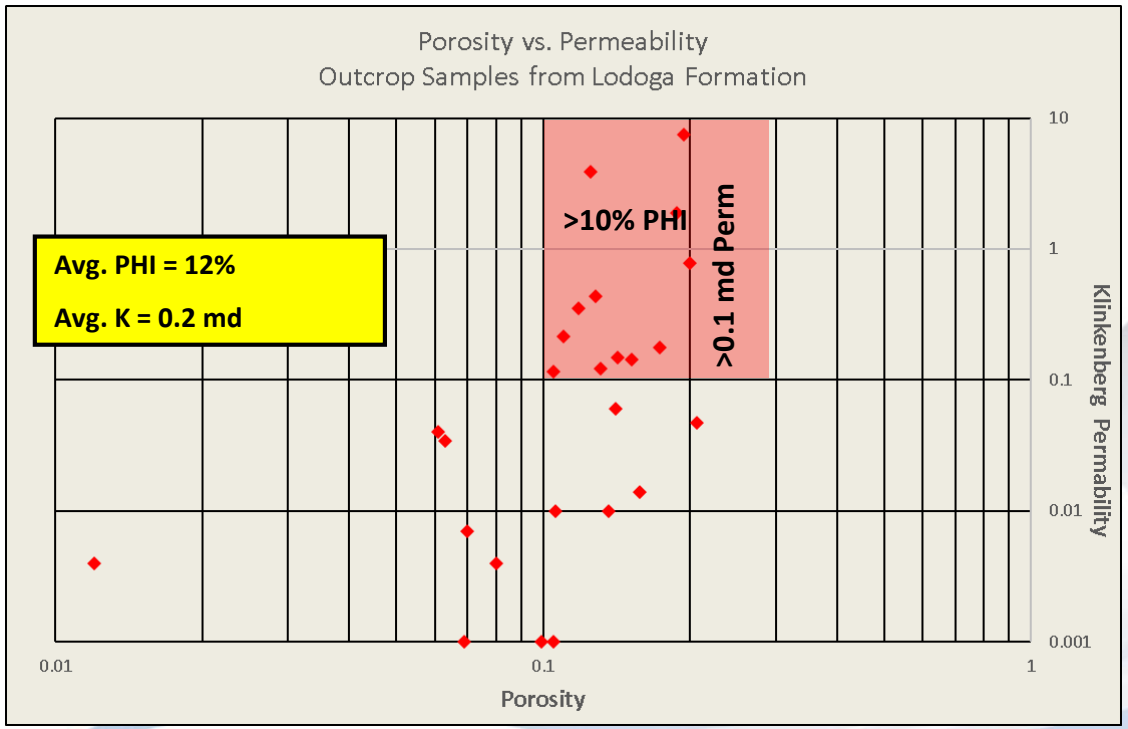




Porosity (%): 12.2
Permeability (md): .152
Grain Density (g/cc): 2.722

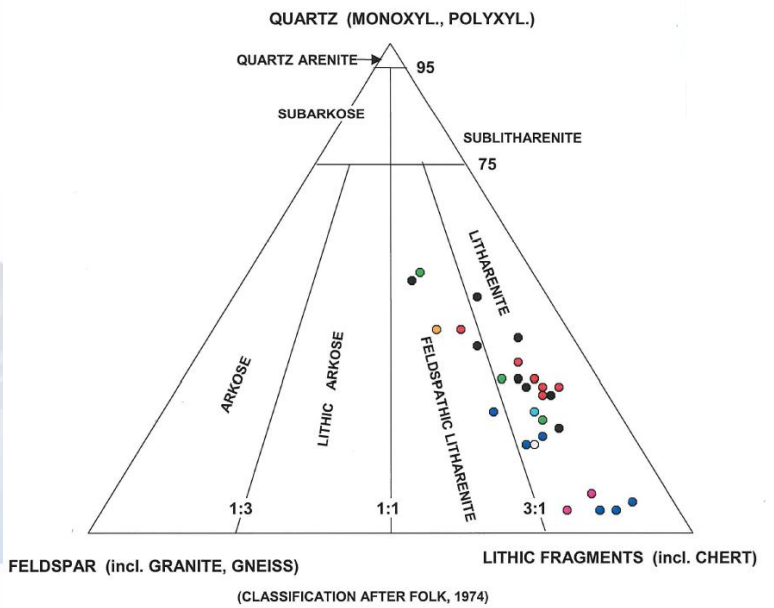
Rock Name and Texture

Lithology: Sandstone
Grain Size (mm): 0.57 (Coarse)
Sorting: Moderately to Poor
Roundness: Subangular-Subround.
Structures: Faint lamination

Rock Composition (Visual Estimate*)

Framework Grains:

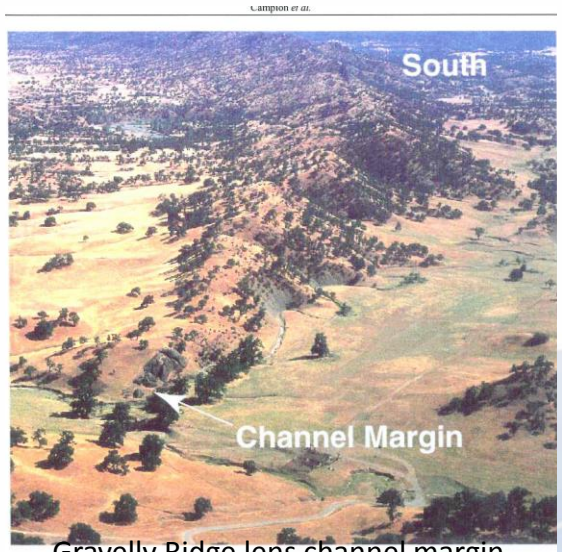
Mafic VRF (basaltic)
Chert
Argillaceous RF
Felsic/Intermediate VRF



Lodoga Sandstone Channel

Outcrop along Sites-Lodoga Road showing incised channel of sandstones into a finely laminated siltstone
(Kevin Weberling for scale!)

Detail of finely bedded sandstone in Lower Lodoga outcropping in Stoney Creek near Stoneyford



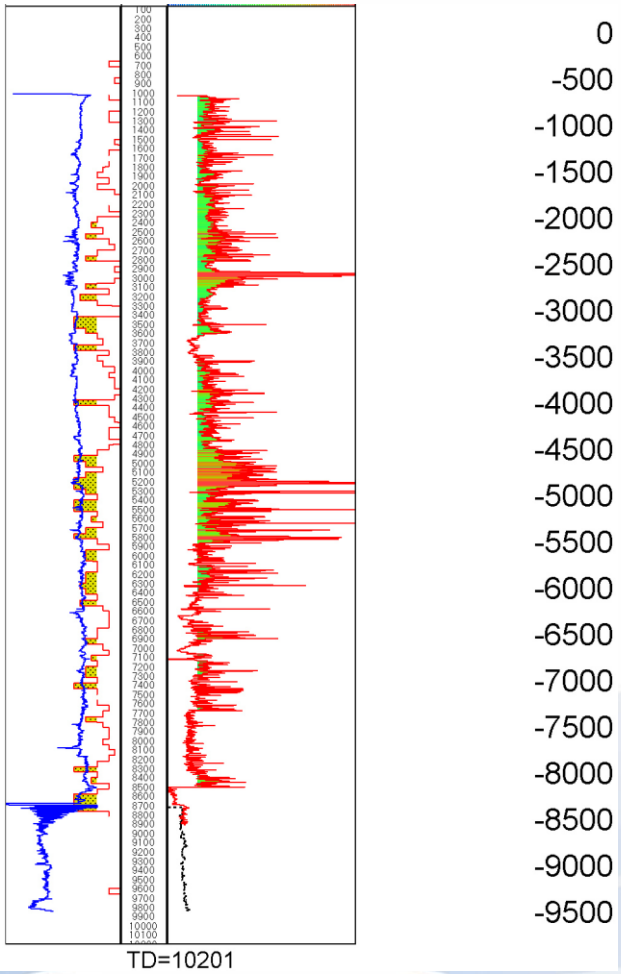
Gravelly Ridge lens channel margin
Elk Creek, CA (*Campion el al, 2000*)

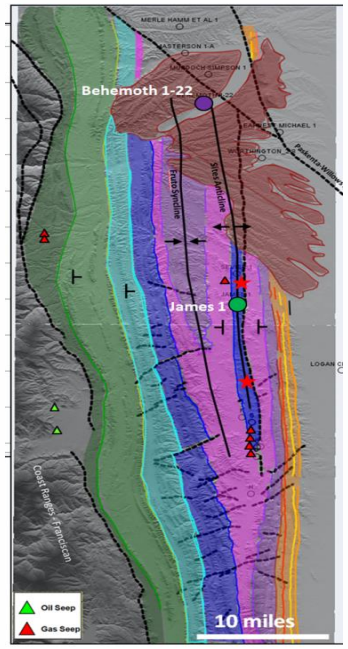
Detail of the complex bedding sequences in the turbidite channels. Many mini-Bouma sequences

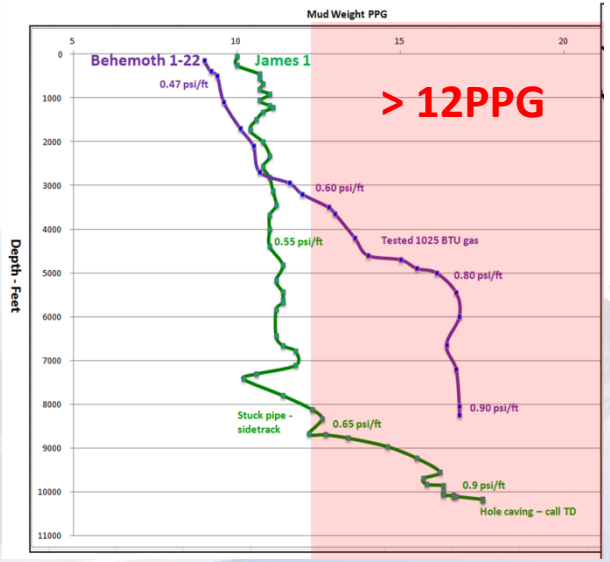
Exploration History Lower Cretaceous

- 1925 – Conoco drilled to planned TD of 4,000'
  - P&A at 1,876' due to pipe collapse. Gas shows.
- 1940's – 1950's – Std Oil & Gulf drilled wells exploring for oil
  - All wells had to **"mud up"** for high pressured gas
  - Natural gas was not commercial in this era
- 1949 – Shell James #1 drilled deepest well on structure to 10,201' TD
  - **20 ppg Mud weight** while drilling
  - Tested gas and fresh water
  - Shell was targeting oil on this anticline and abandoned the well
- 1960's – 1970's
  - Several wells drilled along the structure
  - All wells found high pressure gas at shallow depths (<2500')
  - All of the wells had **heavy mud weights** due to higher pressured gas encountered
- 1978-83
  - Shell acquired a series of 2D seismic lines across Sites Anticline
    - Recorded 10 seconds of data (Usual data in Sacramento Basin recorded 3 seconds)
      - Plate tectonics needed to be considered in new interpretation
    - Deeper structural aspects of the anticline were better understood with these data
- 1990's -2000's
  - Hamar Behemoth 1-22 1998 – shows with gas recovered on DST
  - Vintage (CRC) Tulainyo #1 – 2014 – shows on three redrills, hole lost due to mechanical issues
  - PEOCO Dempsey #1 – 2017 – **DISCOVERY!!!** In Rancho Capay Field - Sacgasco (ASX: SGC)
  - CRC Tulainyo #2 – 2018 – Testing presently (ASX: PCL)

Shell James #1



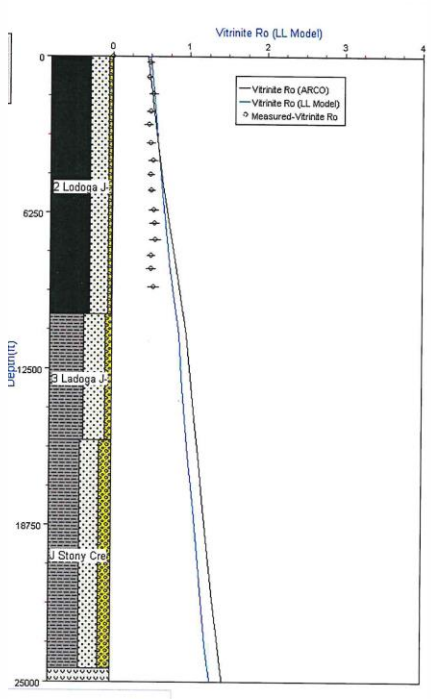




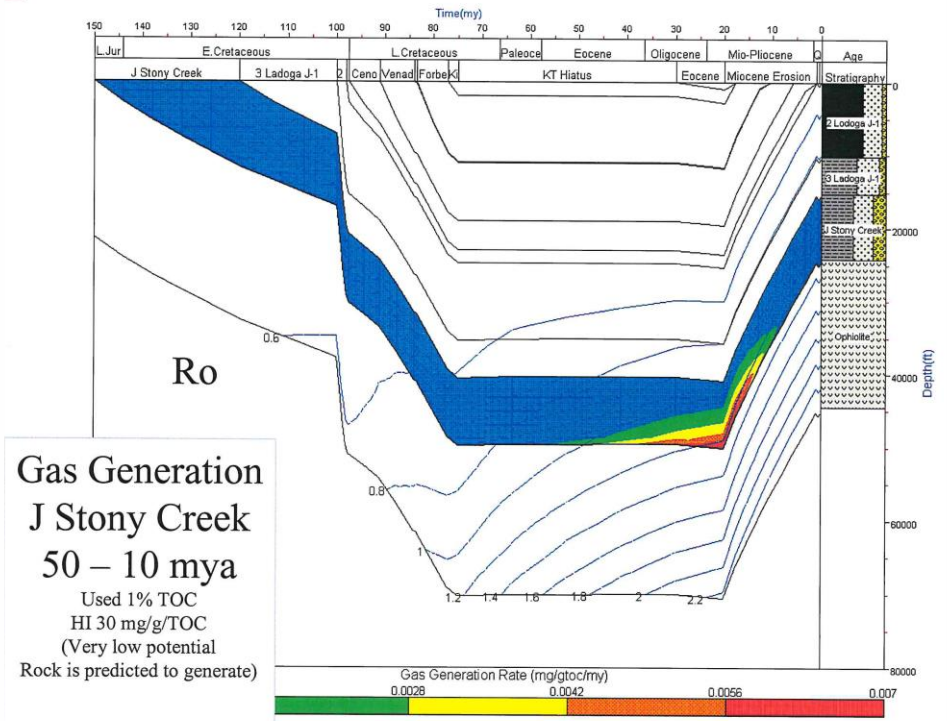
Central and North Sites Anticline

- **Shell James #1** and all others on anticline were drilled with very heavy drilling fluid due to high gas shows.
  - Shell James #1 had mud weights over 20 lb/gal in well from **March 1949** till **July 1949 (5 months)!**
  - Well tested gas with fresh water
  - Water had to be Filtrate due to low salinity
- **Hamar Behemoth 1-22** drilled in 1998
  - Saw overpressure at 3,000’ on north end of anticline
  - Drilled to 8,429’
  - Numerous gas shows (1025 BTU)
  - Not deep enough to adequately test Lower Cretaceous reservoirs
  - Well tested thinner zones with possible formation damage due to heavy drilling fluid (16.8# mud)

Burial History Modeling for The West Side Based on Shell James #1



Ro of rocks in Shell James #1 are ~0.6 from surface to 10,100’



Burial is almost continuous through Cretaceous, providing accommodation space for the Guinda, Forbes, et al

Gas Generation appears to be a recent (< Miocene) event

- Subducting “cold” slab retarded geothermal gradients
  - Migraton of triple junction ceased subduction and increased local geothermal gradient
- Source rock is relatively low quality
  - 1.0-2.0% TOC Type IV

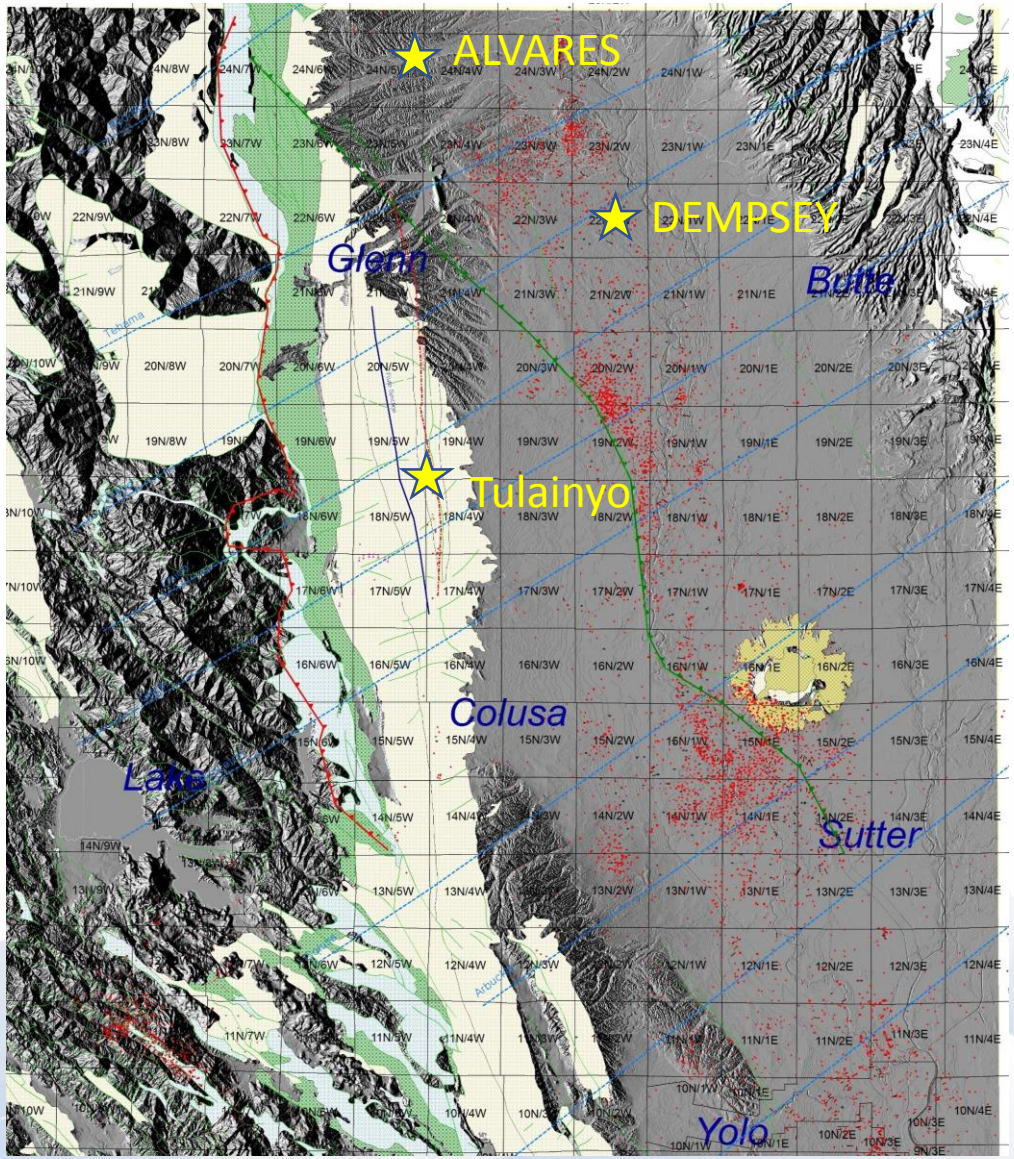
Over Pressured Target Reservoirs
Why have these targets not been exploited until recently?

- The old *folklore* in the Sacramento Basin was that "super-pressured" was bad
  - Some Chevron wells at Moon Bend Field in the late 1970's created that myth
  - Overpressured gas was thought of as always to be associated with water
- Every successful unconventional gas play in the world is overpressured (~0.6 to 0.85 psi/ft)
  - Basin Centered Gas is better understood in both clastics and shales
- West side L K rocks have exhibited overpressuring (> 0.70 psi/ft)
- Gas generation occurring in Lower K/Upper J and migrating to the east into younger reservoirs
- Tendency by California operators is to answer this with excessive mud weight
  - Other plays use pressure control methods and flare stacks
  - Excessive mud weight can cause formation damage due to water sensitivity and imbibement

Recent Exploration Activity

Australians have taken the ball and supported recent exploration efforts

Recent and Planned Drilling



Sacgasco (ASX: SGC) in partnership with PEOCO Drilled the Dempsy 1-15 to ~9750' to test Lodoga Formation

Dempsey Project - Schematic

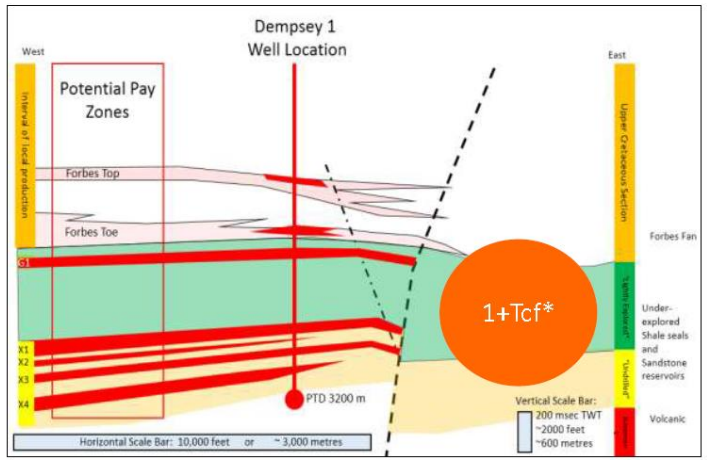
Appraisal/ Exploration - 1+ Tcf*

Reduced Risk - 7 stacked independent conventional sand reservoirs

High Potential - Total (100%) deterministic un-risked recoverable prospective resource: 1+ Tcf

High Probability of Success - Multiple independent targets ranging from 1+ Bcf to 350+ Bcf

Speed to Market - Located within existing and producing gas fields with quick access to markets



* Further details were included in the Company's ASX release dated 4 September 2014.
"The estimated quantities of petroleum that may potentially be recovered by the application of a future development project(s) relate to undiscovered accumulations. These estimates have both an associated risk of discovery and a risk of development. Further exploration appraisal and evaluation is required to determine the existence of a significant quantity of potentially movable hydrocarbons.

SACGASCO

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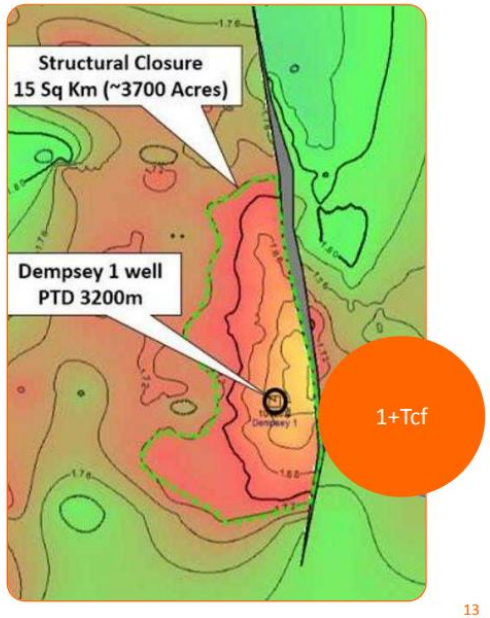


13

Working Interests (WI) in the Dempsey Gas Project:

Sacgasco Limited (ASX: SGC) (Operator)	50%
Empyrean Energy PLC (LON: EME)	30%
Pancontinental Oil and Gas NL (ASX: PCL)	10%
Xstate Resources Limited (ASX: XST)	10%

Dempsey 1-15 Gas Flare

Dempsey well is producing ay low rates with multiple zones to be tested!

http://www.sacgasco.com/wp-content/uploads/2017/11/2017.11.14-ASX-SGC-Dempsey-Gas-Well-Testing-Update.pdf
http://www.sacgasco.com/wp-content/uploads/2017/06/2017.06.26-ASX-SGC-Dempsey-Well-Update-Corporate-Presentation.pdf

Confluence RESOURCES

Sagasco is planning a re-entry of a 1982 wells drilled by American Hunter

- Great gas shows in Lower Cretaceous
- Drilled with heavy mud – most likely damaged water sensitive sands
- Well tests yielded low rates

Alvares Project

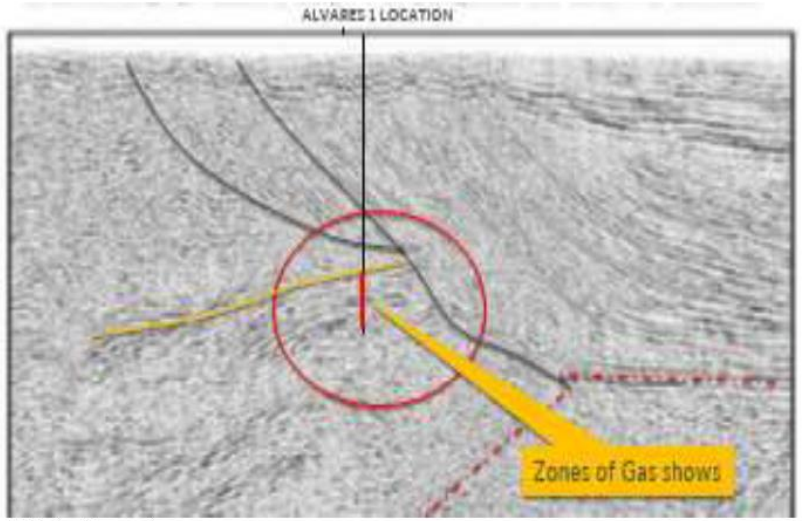
Appraisal/ Exploration - 2+ Tcf* Gas

Reduced risk – **Overlooked** conventional natural gas discovery drilled in 1982 when looking for oil

High Upside - 1500+ metres of gas shows with gas flow to surface

Highly prospective - On trend with analog Tulainyo and James wells with multiple stacked gas filled conventional sands in a mapped multi-Tcf prospect

Massive potential - 100% un-risked recoverable prospective resource of 2+ Tcf, only 13 Kilometres from major pipelines



Published Texaco line

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SACGASCO

14

From the Sagasco website

http://www.sacgasco.com/wp-content/uploads/2017/06/2017.06.26-ASX-SGC-Dempsey-Well-Update-Corporate-Presentation.pdf

CRC Analyst Day Slide describing a farmout opportunity to attract capital to drill a follow up well to Tulainyo #1

CRC 2017 Analyst & Investor Day

March 22, 2017 | Bakersfield, California

CALIFORNIA RESOURCES CORPORATION

Exploration Activity

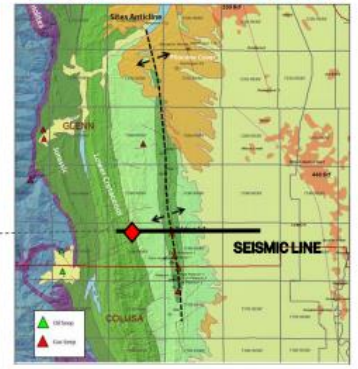
- **CRC Exploration Program**
  - Conventional Deeper Primary prospect with stacked pay potential over 6,000' gross interval
  - Drill location within CRC-Operated field
  - Further delineates 20+ mile play trend
- **Joint Ventures**
  - San Joaquin Basin conventional Deeper Primary prospect analogous to BV Nose
    - 3rd party pays 100% of costs to acquire 3D seismic and drill one well
  - Sacramento Basin gas prospect
    - 3rd party pays 100% of costs to drill up to three exploration wells
  - Actively pursing additional joint ventures

Sacramento Basin Gas Prospect

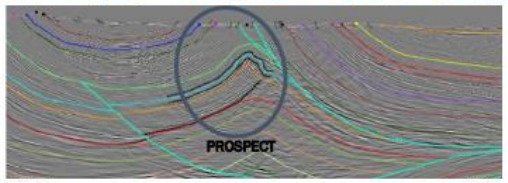
- 50+ square mile (32,000 acres) 4-way closure with stacked reservoir potential, mappable at surface and on proprietary 2D seismic
- Previous CRC drilling encountered 2 high-pressure gas sands
- ~ 5 miles to PG&E trunk line

Extensive reservoirs outcrop at surface

Surface geology map and satellite imaging shows presence of 4-way structure



Reservoir outcrop projected into prospect via proprietary 2D seismic



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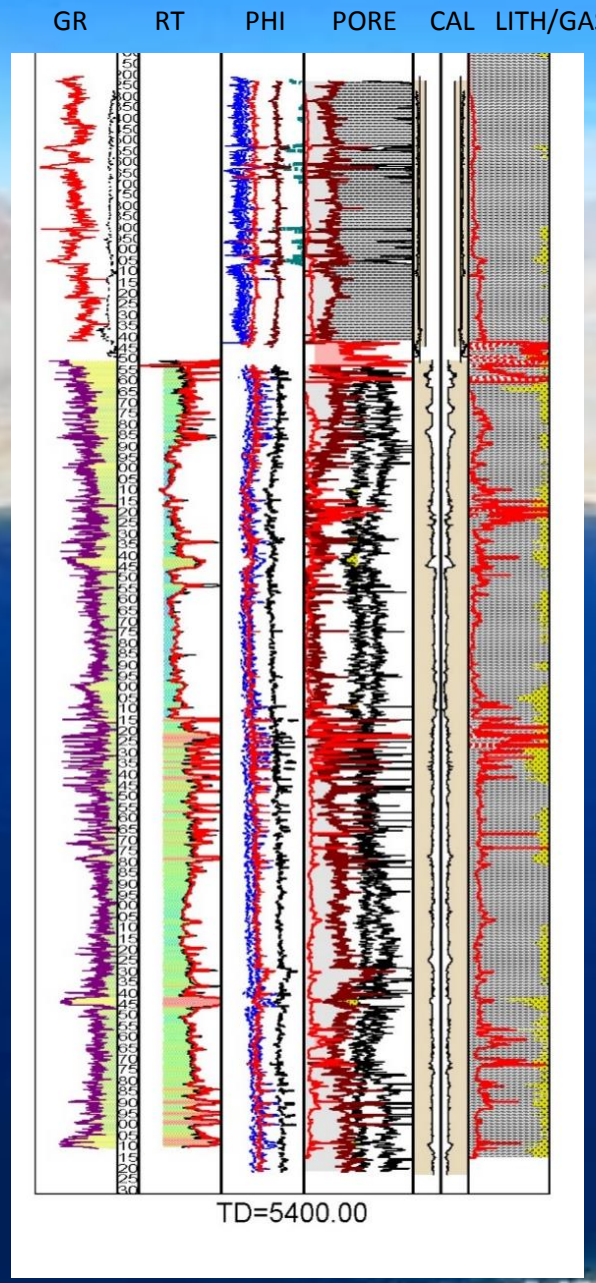
61 | 2017 CRC Analyst Day

Tulainyo #1 Side Track 3

Information From the California DOG site

Prospect developed by Cirque Resources who brought in Occidental as a partner in 2011

- **High effort 2D seismic data acquired 2012**
- **Well spud December 2014 the same month that Oxy formed CRC as a separate company**
  - **ST 1 and ST2 on east flank of Sites Anticline**
  - **ST3 saw dip change to west flank**
    - **MW > 18.5 PPG**
  - **Stuck drillpipe on cleanout run preparing for casing run.**
- **Tulainyo #2 spud December 2017 with new partners Pancontinental (ASX: PCL) et al**
  - **Presently testing**



Tulainyo Lake
12,828’ above SL

Recent Seismic Data over Sites Anticline showing the Tulainyo Prospect and the proposed Tulainyo #2 well (well presently testing)

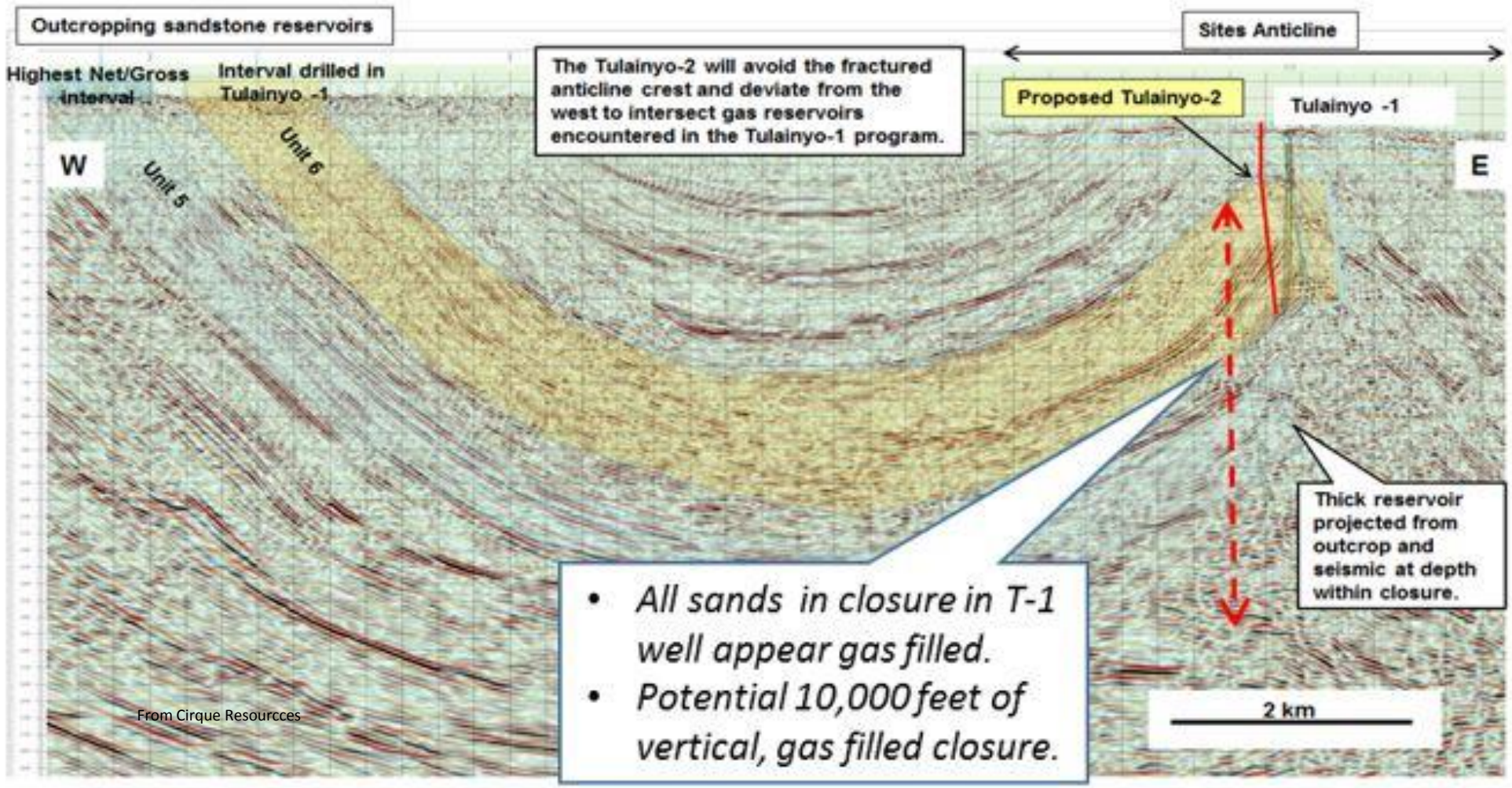


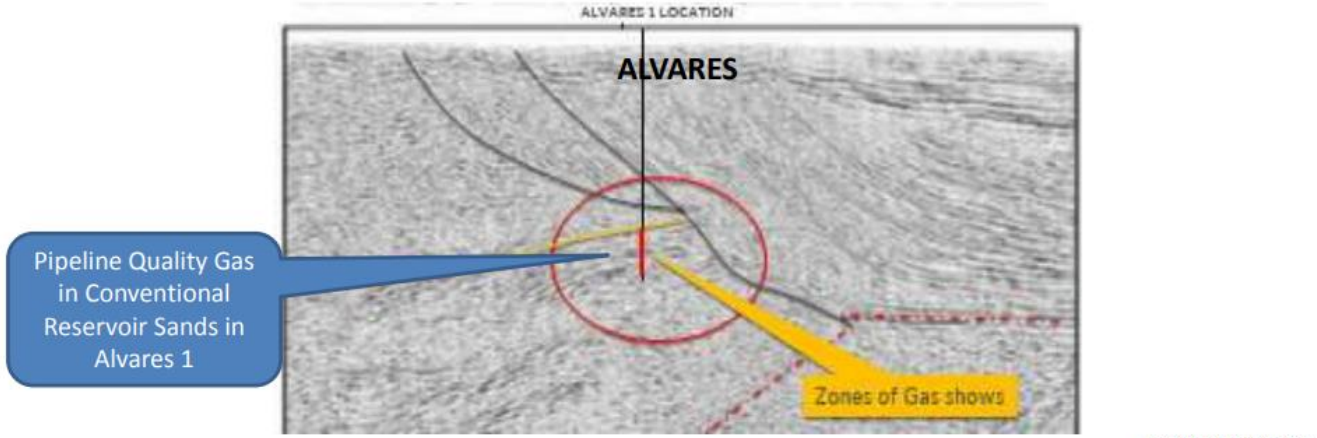
Figure 3 Seismic Line Across the Tulainyo Gas Discovery

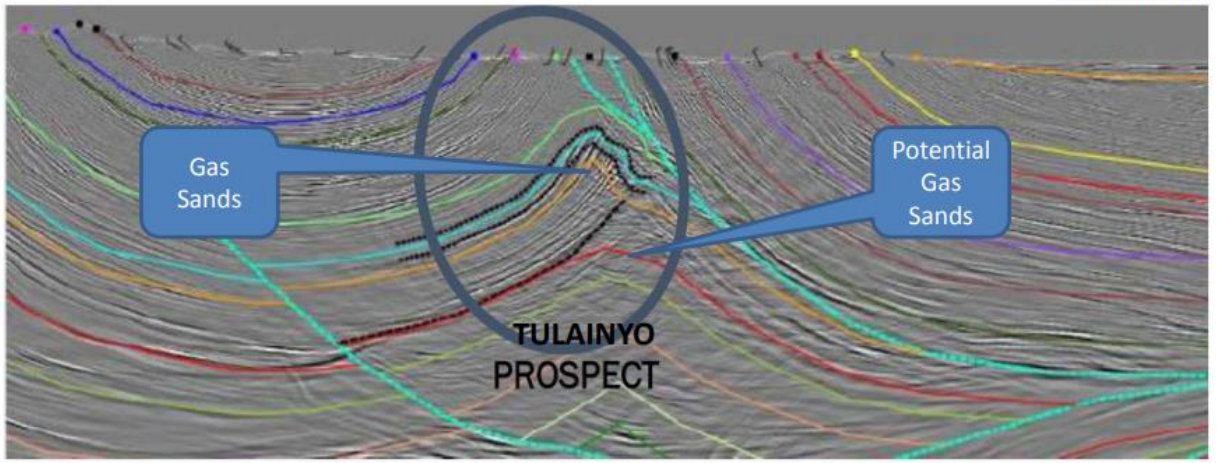
From Pancontinental Analyst Report June 2017

http://pancon.com.au/project/sacramento-gas-basin-tulainyo-gas-discovery/

Comparison of structure at Tulainyo and Alvares Prospects

- Sites Anticline is a true anticlinal structure
- The structure at Alvares appears to be a thrusted block
- Potential structural complications offer potential





SACGASCO

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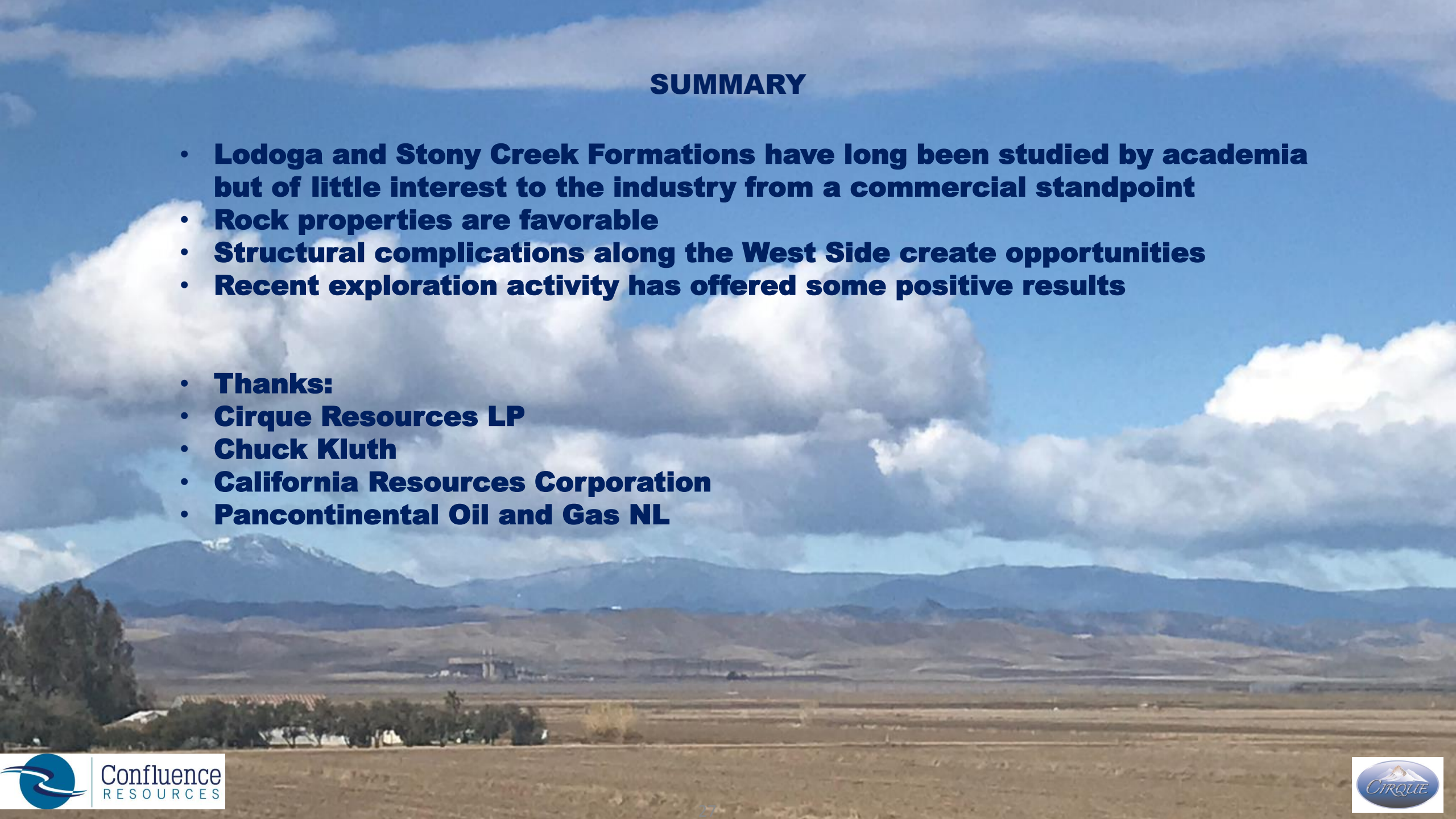
http://www.sacgasco.com/wp-content/uploads/2017/05/SGC-April-2017-investor-presentation-1.pdf



SUMMARY

- Lodoga and Stony Creek Formations have long been studied by academia but of little interest to the industry from a commercial standpoint
- Rock properties are favorable
- Structural complications along the West Side create opportunities
- Recent exploration activity has offered some positive results

- Thanks:
- Cirque Resources LP
- Chuck Kluth
- California Resources Corporation
- Pancontinental Oil and Gas NL