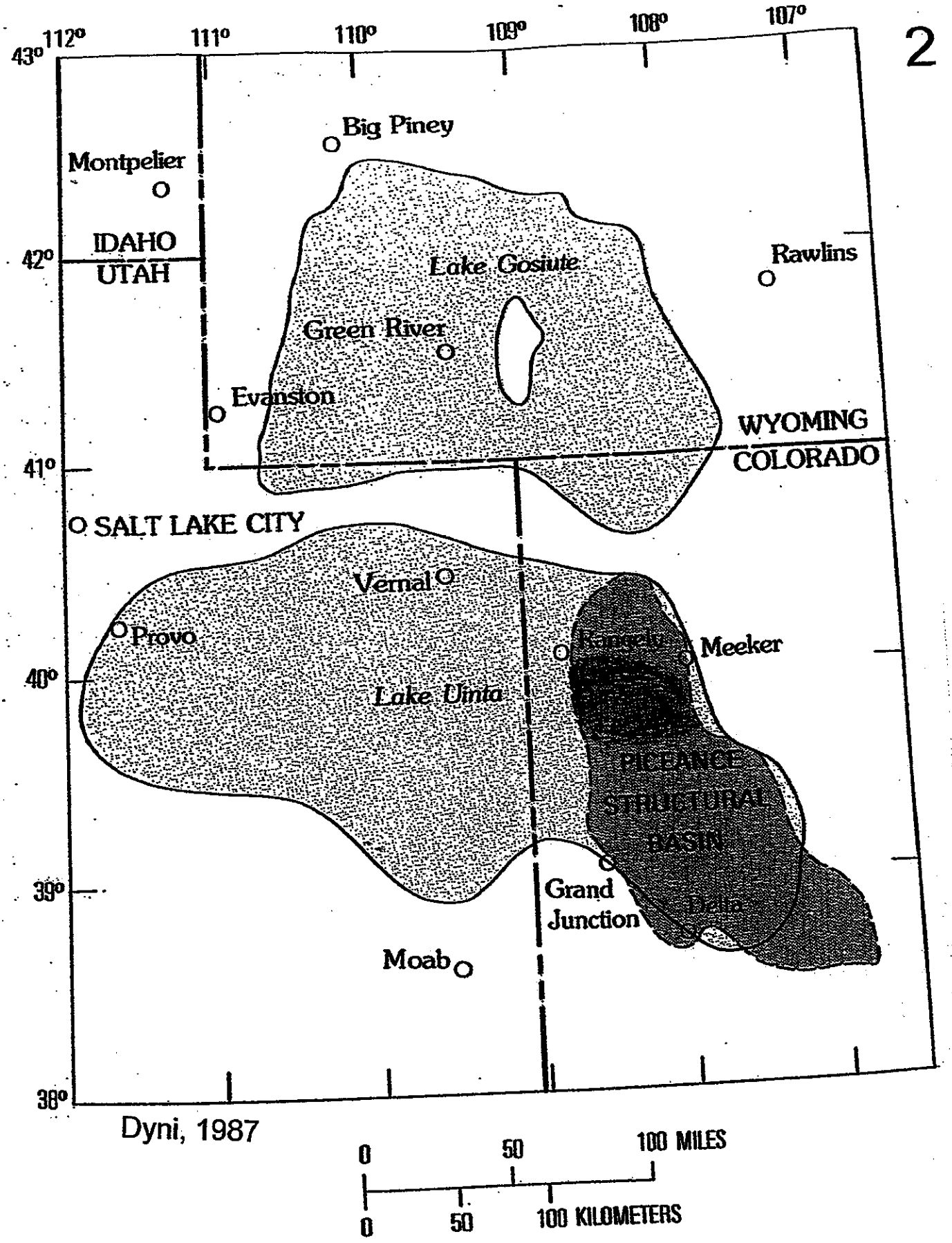
Colorado Energy Research Institute
Colorado School of Mines

28th Oil Shale Symposium
October 13-17, 2008

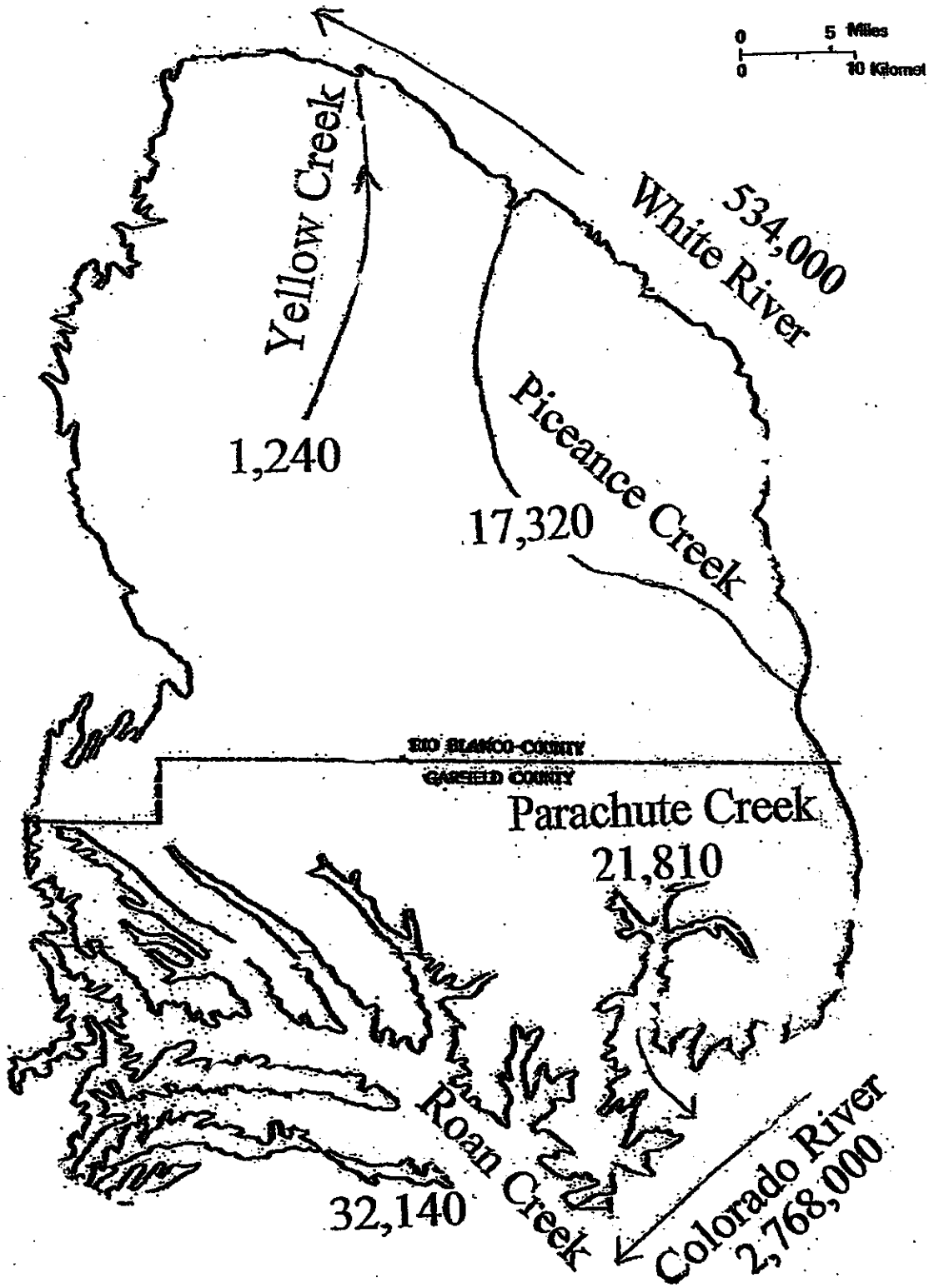
General Perspectives on Methods of Oil Shale Extraction and R&D Needs Piceance Basin, Colorado

Glen A. Miller

Revised



MAXIMUM EXTENT OF ANCIENT LAKES UINTA AND GOSIUTE EOCENE TIME



PICEANCE BASIN
OIL SHALE AREA

LOCAL STREAM FLOW (NEAR MOUTH)
IN AC-FT-YR

PICEANCE BASIN OIL SHALE
THE RESOURCE

One approach is to consider Oil Shale as a National "Bridge Fuel". As I recall, the term "Bridge Fuel" was applied by a researcher during the seventies oil shale boom (my apologies, I don't recall who).

The late Dr. Tell Ertl, a long-time researcher in oil shale, in viewing the future importance of the Piceance Basin resource, wrote in 1965:

> **"If our civilization has any conscience and if it has any regard for posterity, it cannot give serious consideration to any method of production of shale oil from the center of the basin that does not result in substantially complete recovery. Our civilization has passed the stage in which it can kill the whole buffalo merely to consume the tongue and liver as was done in this area less than a century ago." Well Stated!**

RESOURCE - SIZE

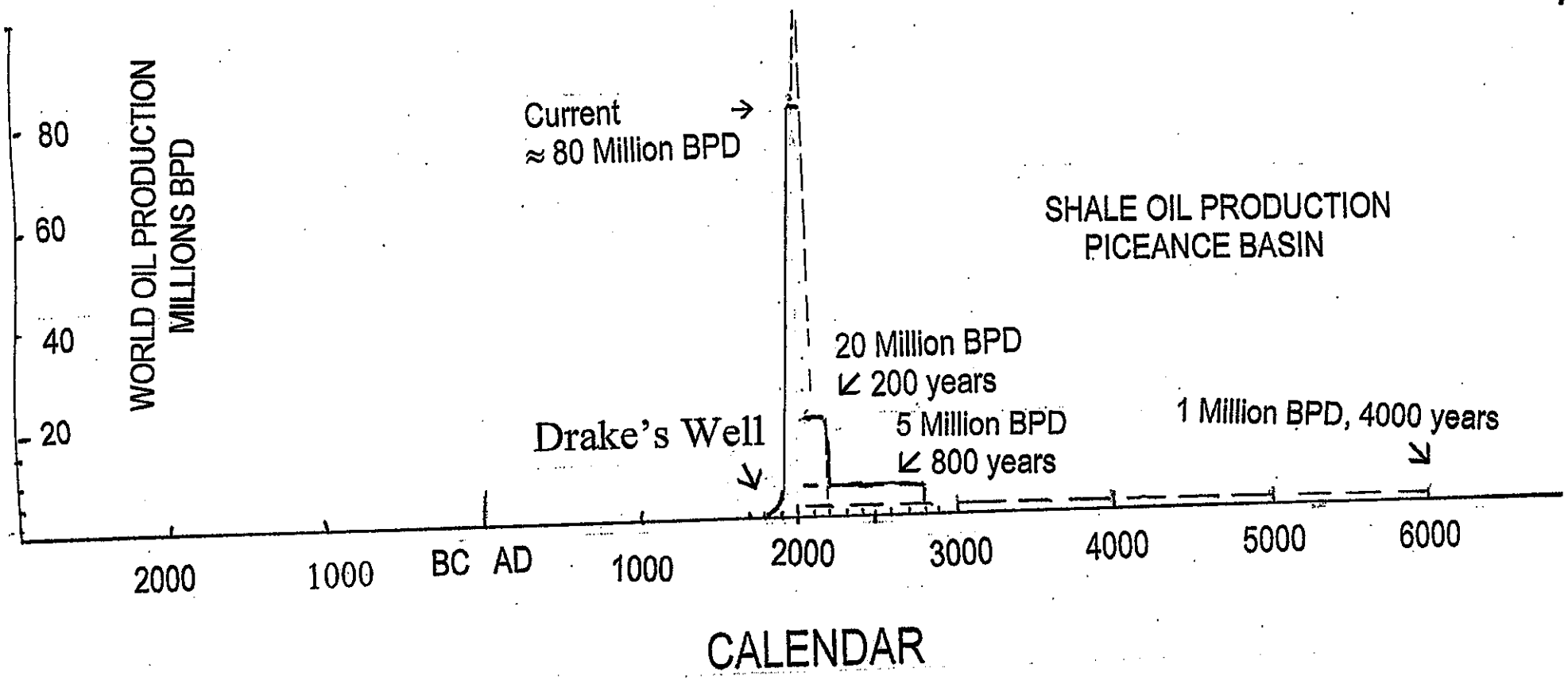
At "cut-off" grades of 15-25 gal/ton, total resource estimates are in the range of 1.2 – 1.3 Trillion bbl. Assume that future "cut off" grade will be at least as low as 10 gal/ton.

Several 100 feet of 10-20 gal/ton shale occur in much of the Basin. In addition, some studies suggest that "retorting recovery" of oil may be as much as 10% more than indicated by Fischer Assay. This assay factor, and including the lower grade shale, may possibly increase the total resource to about 1.5 trillion BBl, and this figure is used herein.

Carl Sagan (Billions and Billions) notes a major stumbling block exists for the human mind to "grasp" the meaning of several million, or a billion, of anything! Failure to understand the size of this resource apparently applies to many who are involved (lay, technical, media, and political entities).

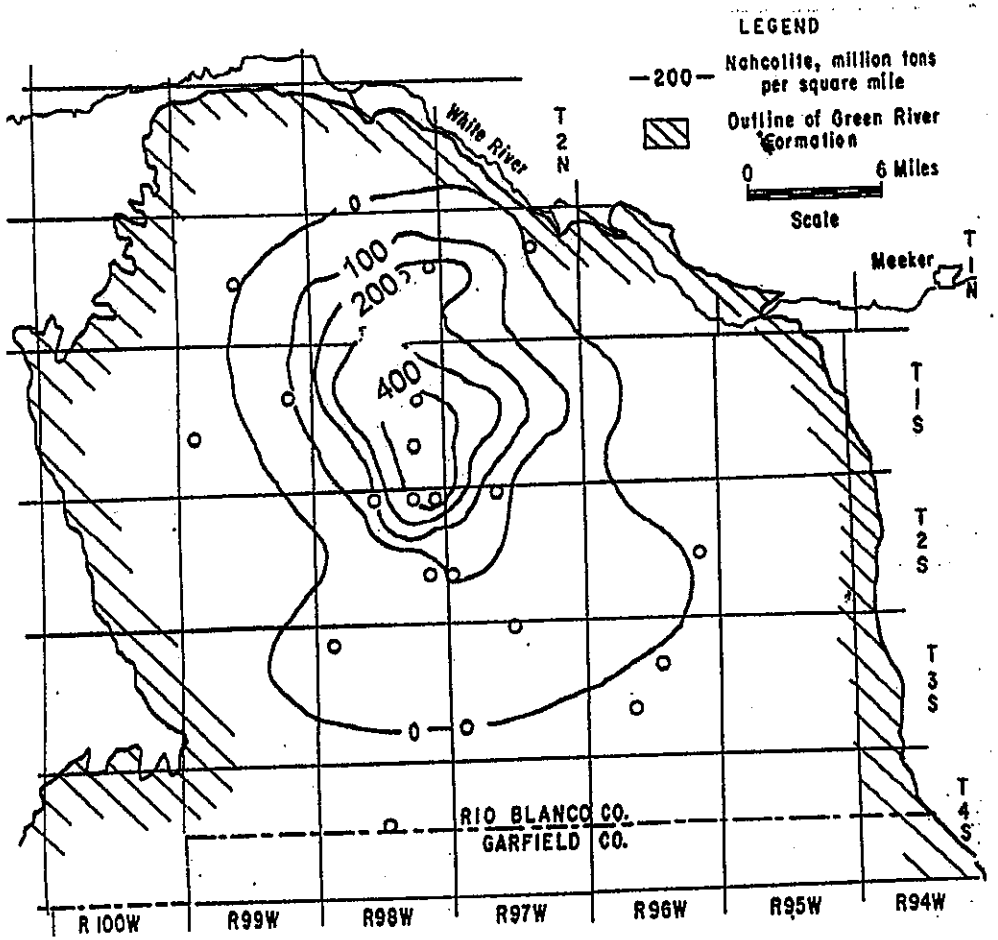
Some comparisons of size may be useful: The 1.5 trillion BBl figure for Piceance Basin is about equal to:

1. **100 Prudhoe Bay fields.**
2. **Eight Lake Powells.**
3. **A three foot cover of oil over a "flat" state of Colorado - or a 1 foot cover on Texas.**
4. **Equivalent in oil to about Seventy-Five years of average annual water in the Colorado River at Glenwood Springs flow (3500 CFS . 1,600,000 GPM 38,000 Bbl/minute or nearly 60 million BPD).**
5. **Feedstock oil for our current Petrochemical industry (about 630,000 BPD) for 6,500 years.**
6. **Supply our current Jet aviation fuel needs for 3,000 years.**
7. **Supply our current 20 million BPD total crude use for 200 years.**
8. **Significantly alter the shape of a diagrammatic, "oil-only", "Hubbert Blip"**



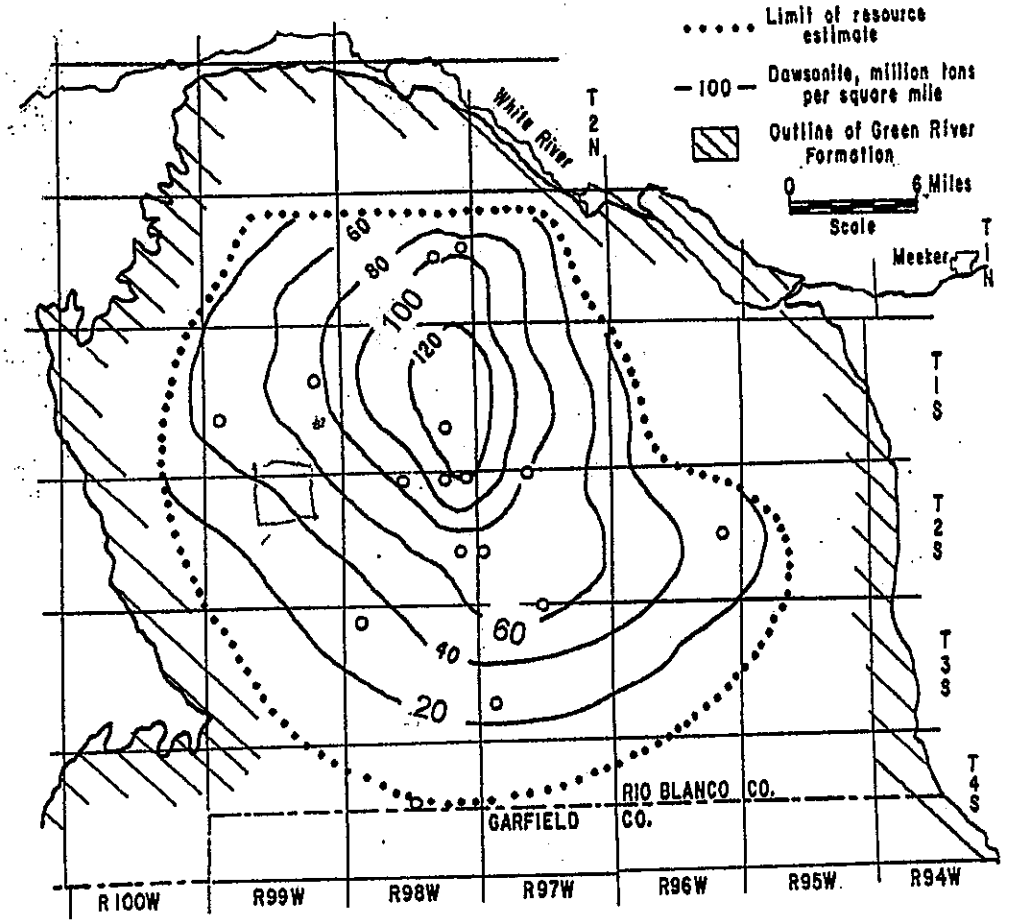
DIAGRAMMATIC "HUBBERT BLIP" (OIL ONLY)

Including Hypothetical Effects of Shale Oil Production, Piceance Basin



Beard & Others, 1974

Nahcolite isoreserves in nahcolite-bearing interval, in millions of tons per sq mi.



Dawsonite isoreserves in dawsonite-bearing interval, in millions of tons per sq mi.

NACHOLITE AND DAWSONITE

29 x 10^9 tons

19 x 10^9 tons

WATER FOR OIL SHALE DEVELOPMENT

Most estimates for water use are in the range of 1-4 bbl water per bbl oil. This paper assumes that 2 bbl water/bbl oil is a reasonable estimate. Air quality issues led to an upper limit on shale oil production in Picence Basin of about half a million BPD. Assume that technology improvements could raise this to 1,000,000 BPD. At 2 BW/BO, this would require about 94,000 ac-ft/yr of water, or about 130 CFS (cubic feet per second).

Potential Local Water Sources (Measured and diverted at stream mouth)

	Flow ac/ft/yr	Potential Shale oil production from these sources (barrels per day)
Piceance Creek	17,320	184,000
Yellow Creek	1,240	13,000
Roan Creek	32,140	342,000
Parachute Creek	21,810	232,300
Total	72,510	771,000

Data Source USGS PP 1310

Colorado River	2,768,000	94,000 AF ≈ 3.4 %
White River	534,000	94,000 AF ≈ 17.6%

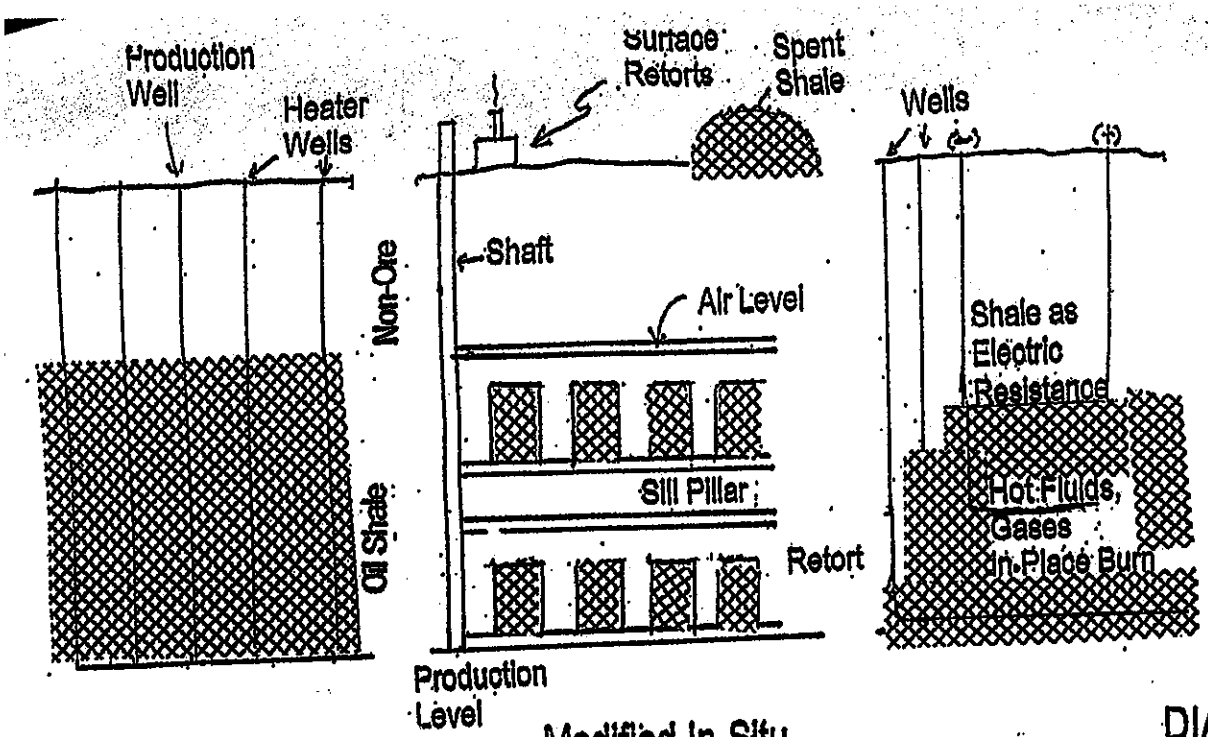
JOINTED ROCK IN OIL SHALE

JOINTS PROVIDE VERTICAL AND LATERAL LEAKY CONDUITS TO MINES, RETORTS, FOR WATER AND GASES. BEDDING ABOUT HORIZONTAL. JOINTS SHOWN ARE ABOUT 1 FOOT APART.

Verbeek & Grout, 1987

Ground water storage 25 million ac-ft.

Dewatering necessary for oil shale production, with annual ground water recharge, would theoretically provide about a 500 year supply for 1,000,000 BPD production. A mix of mine inflow water and local stream flow theoretically would provide water for 1-million bpd shale oil production for nearly a millennium.

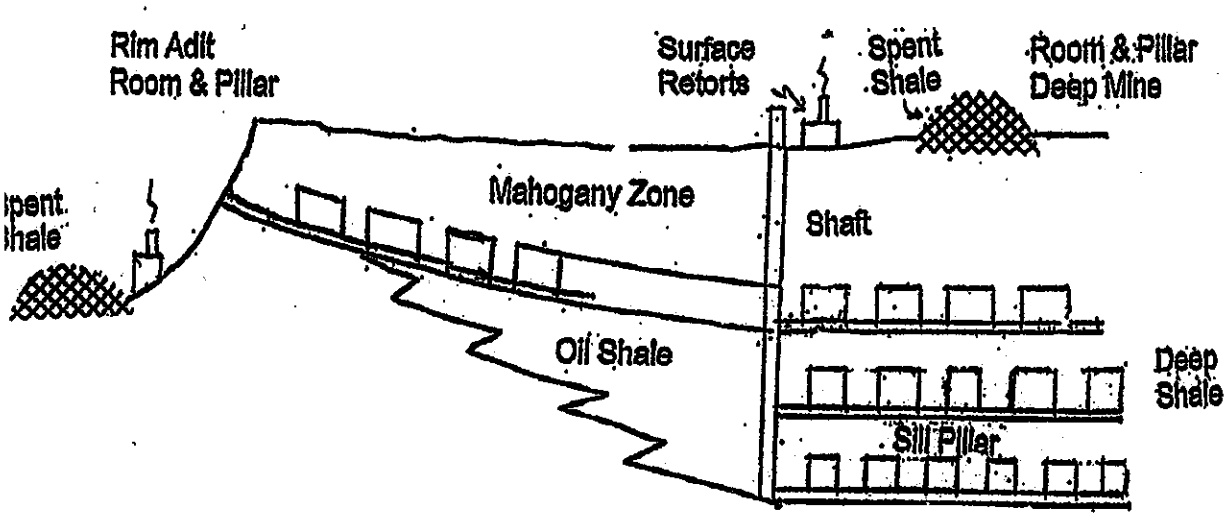


In-Situ

Modified In-Situ
In-Place Burn + Surface Retorts

In-Situ

DIAGRAMMATIC DEPICTION OF SOME PAST ANI PROPOSED OIL SHALE EXTRATION METHODS



Open Cast

SOME COMPARISONS OF OIL SHALE EXTRACTION METHODS

Piceance Basin, Colorado

Emphasis on Resource Recovery, Hydrologic Effects, Land Reclamation

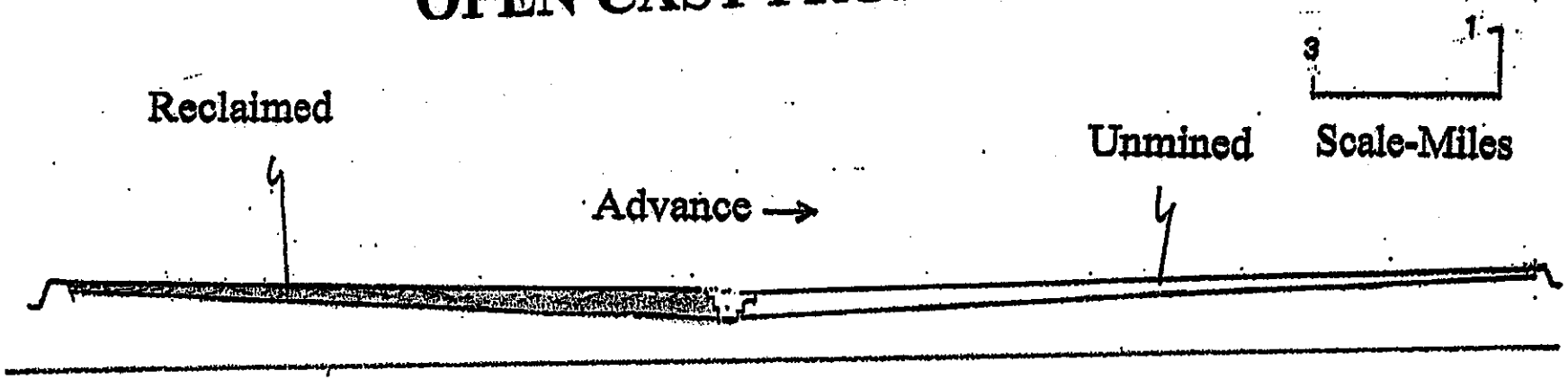
Extraction Methods	Resource Recovery	HYDROLOGY			Land Reclamation
		Ground Water	Surface Water	Water Use 2BW/BO	
Room and Pillar (R & P) Surface Retorting	< 50-75% ± recovery; Nacholite and Aluminum recovery.	Dewatering, shale leachate to water; subsidence	Dewatering effect on streams, springs, shale leachate, subsidence.	75% ± for spent shale management; surface reclamation; R&D needed to reduce water needs.	Surface spent shale a long-term problem. Widespread subsidence effects.
In-Situ (IS), Modified In-Situ (MIS)	30-80%. No (?) Nacholite or Dawsonite recovery	Dewatering, significant problem w/spent shale leachate. Subsidence.	Dewatering effects on springs, streams, subsidence.	Water usagefor retort clean up, surface reclamation.	Subsidence effects on surface drainage, topography. Surface disposal of spent shale – (MIS only).

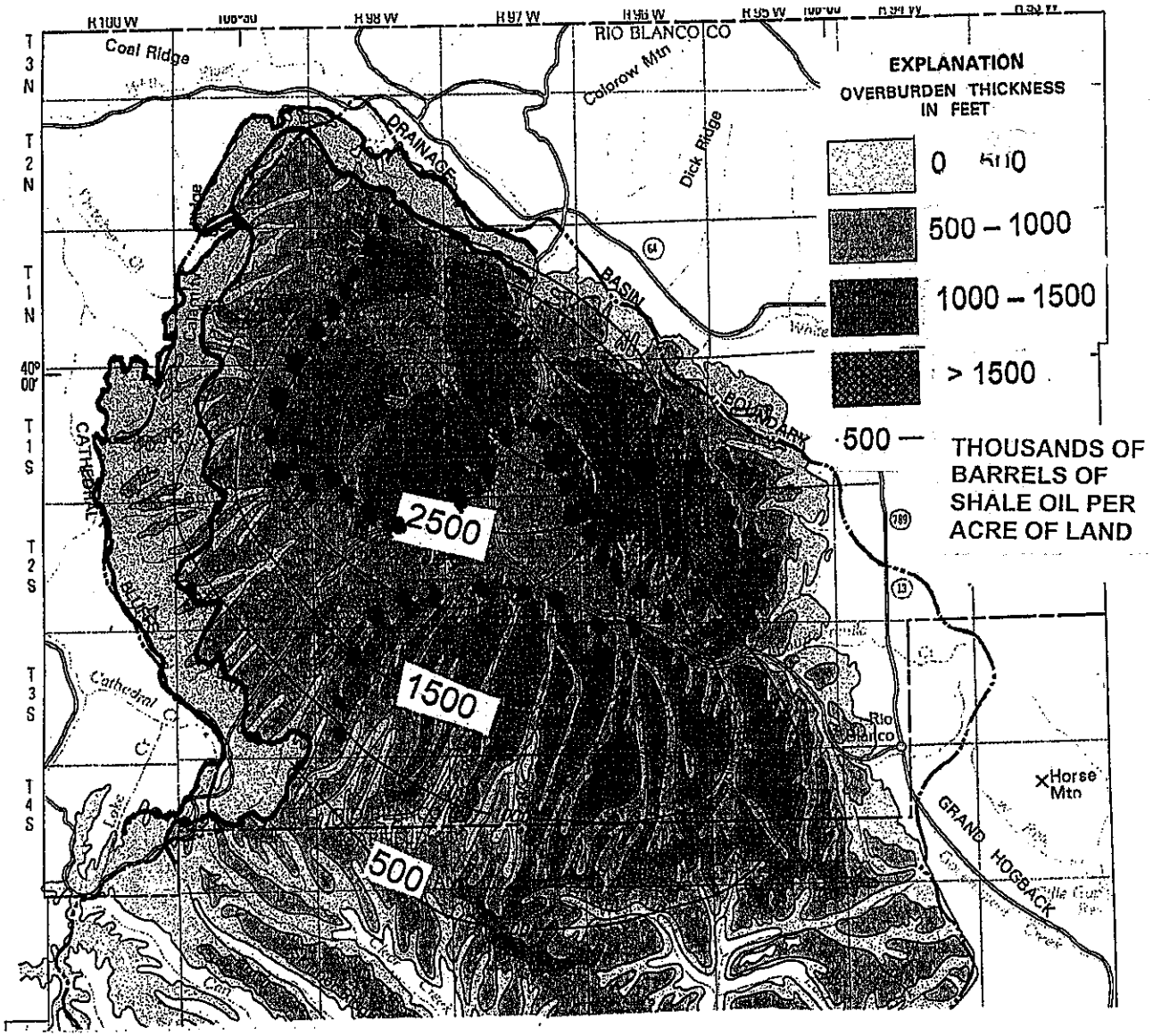
SOME COMPARISONS OF OIL SHALE EXTRACTION METHODS

Extraction Methods	Resource Recovery	HYDROLOGY			Land Reclamation
		Ground Water	Surface Water	Water Use 2BW/BO	
Open Cast	Near 100% (ore), including Dawsonite and Nahcolite	Dewatering; leaching through shale-backfill. Spent shale appears controllable. Reclaimed Aquifer storage perhaps +50 MAF	Disruption of streams, springs. On-going reclamation necessary.	Most of water use for spent shale management, revegatation.	Most promising method. Wide range of materials for increased soil productivity. Minimum subsidence.
Summary: Most aspects of open cast superior to other methods.	R&P, MIS, IS, Non-recovery of 30-50 "Prudhoe Bays". MIS, limited Dawsonite-Nacholite recovery. Open cast, near 100% recovery of all resources.	Open-cast significantly fewer unwanted long-term effects. Increased aquifer storage	IS, MIS, saline groundwater and subsidence effects onstreams. Post Open-Cast surface drainage can be "designed".	R&D needed to minimize water use for all technologies.	Open-cast significantly superior to other methods. Spent shale control, soil redistribution increases productivity.

Note: As to the above comparisons, the Author has some knowledge, experience. In so far as other effects, conditions, etc, the Author is not well informed

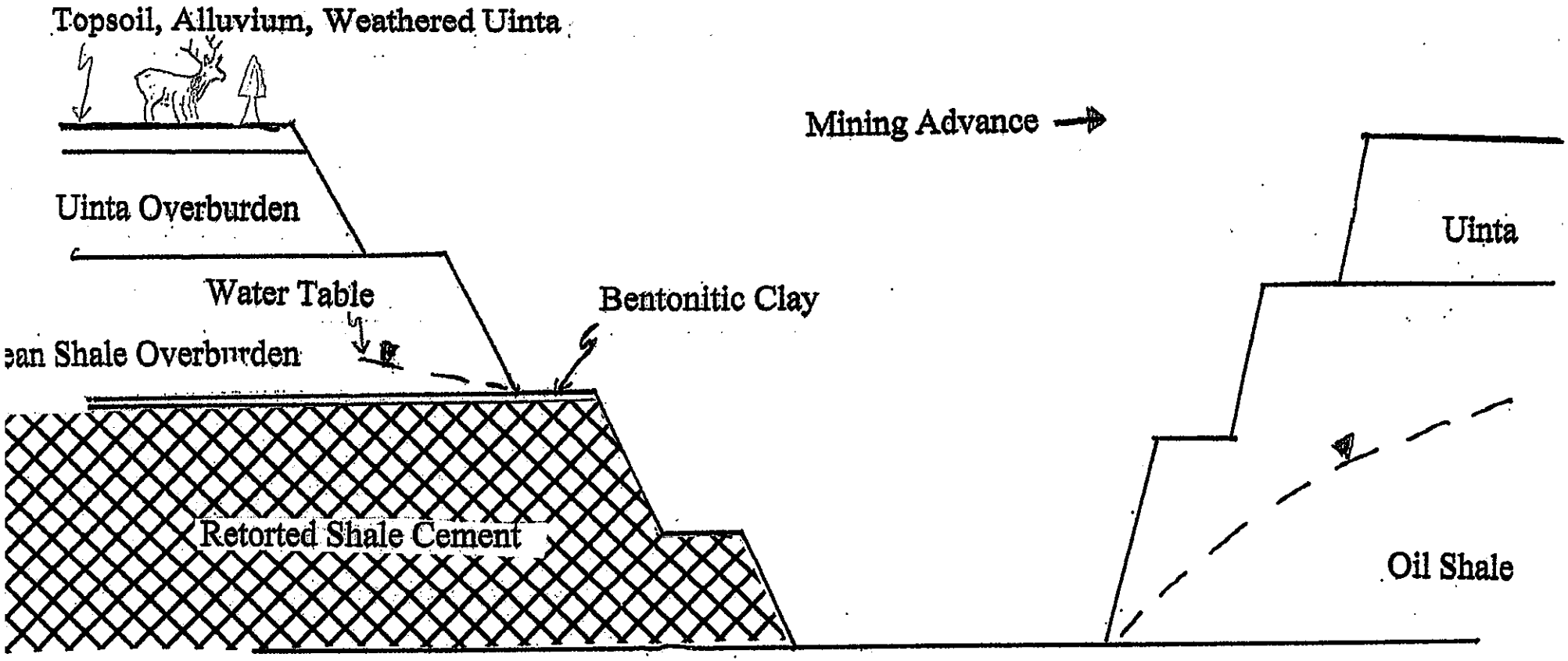
OPEN CAST PROFILE



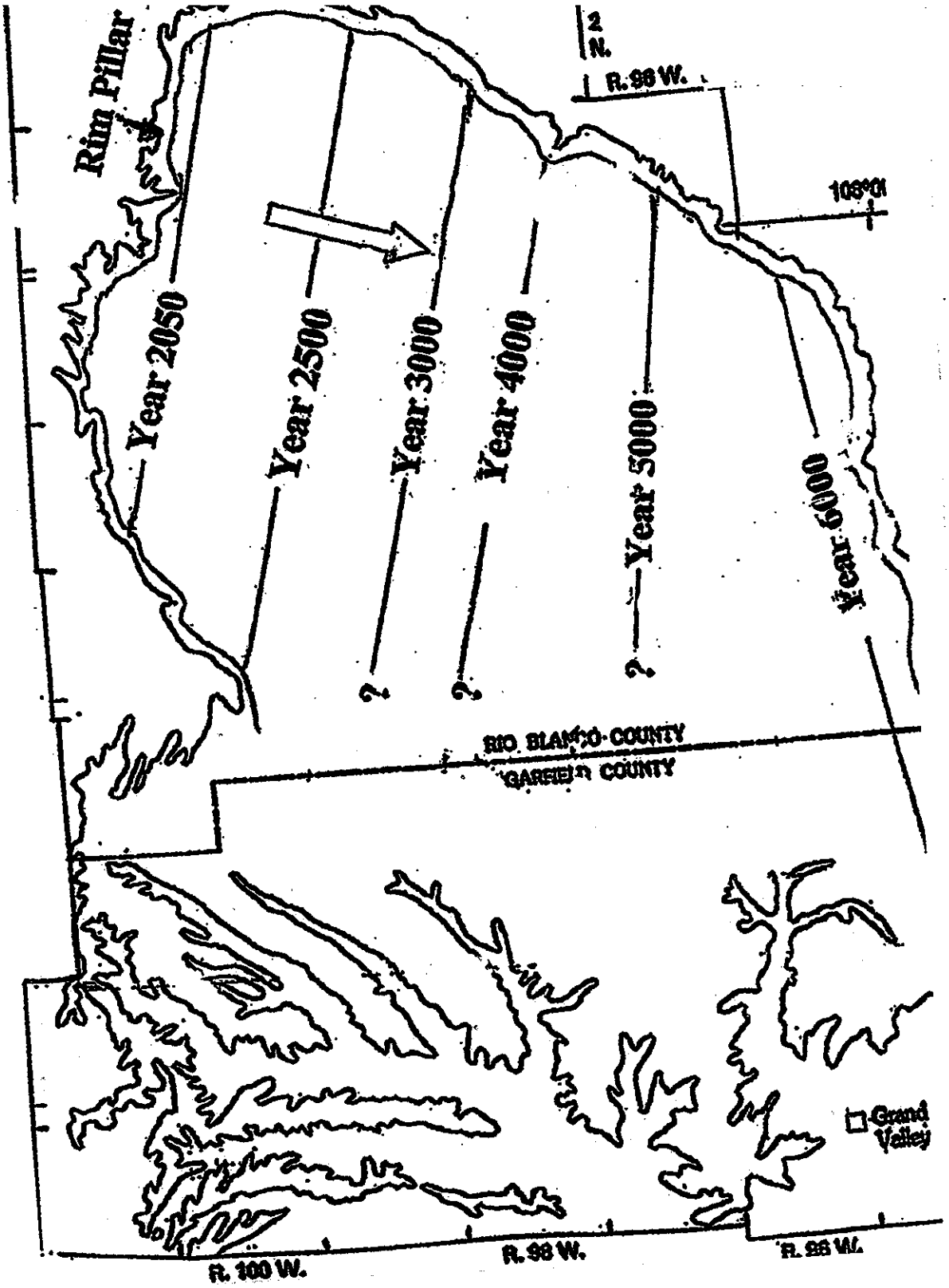


Donnell, 1987

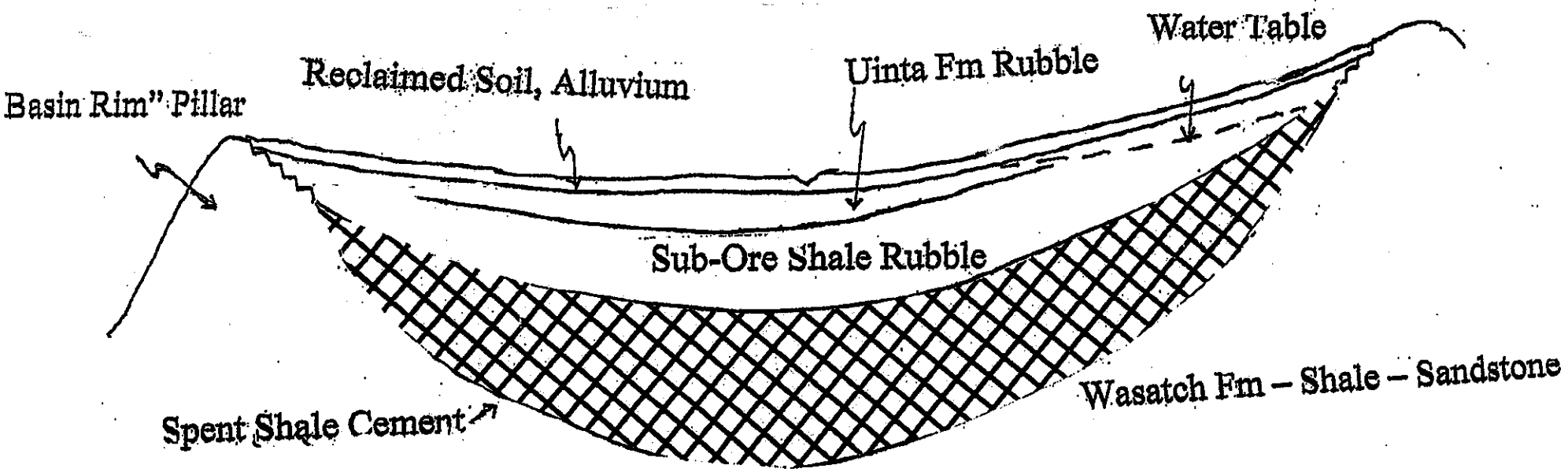
Total shale-oil resources, overburden thickness above Mahogany zone



DIAGRAMMATIC SECTION
Open Cast Cut



DIAGRAMMATIC DEPICTION
OPEN CAST MINE
Progression Dates Across Basin
At 800,000 BPD



DIAGRAMMATIC BASIN-WIDE SECTION

Post-Reclamation Conditions

NOTE

The 2007 BLM Draft Oil Shale EIS Notes, in an unexplained but unfathomable leap of reasoning as to resource management, that:

1. **No R & D proposals for surface mining.**
2. **Revise the 1986 Resource Management Plan to ban any surface mining in Piceance Basin.**

The 2008 BLM RMP Changes/Final EIS (V-1, p 3-10) apparently allows surface mining, but excludes from such mining about 87% of the area (probably 95% of the resource). The excluded area contains almost all of the NW area of less than 500 feet of overburden.