Underground Nuclear Tests and Other Worst-Case Analogues for Geologic Waste Isolation

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ὁ δὲ ἀνεξέταστος βίος οὐ βιωτὸς ἀνθρώπῳ (Socrates)

the unexamined life is not worth living (for a *proper* human being)

Common unexamined assumptions in radioactive waste sequestration:

The fascinating impressiveness of rigorous mathematical analysis, with its atmosphere of precision and elegance, should not blind us to the defects of the premises that condition the whole process (T. C. Chamberlin, 1899)

- Liquid waste must be solidified before geologic disposal
- New excavations are better than old mines
- Known mineral resource areas should be avoided
- Radioactivity is more insidious than chemical toxicity
- **Heat generating waste presents special threats**
- We must understand everything "perfectly"
  - down below the yocto (10^{-24}) scale
  - up above the n^{th} dimension
  - before deciding to do anything

Your system is perfectly designed to give you the results you're getting

(W. Edwards Deming)

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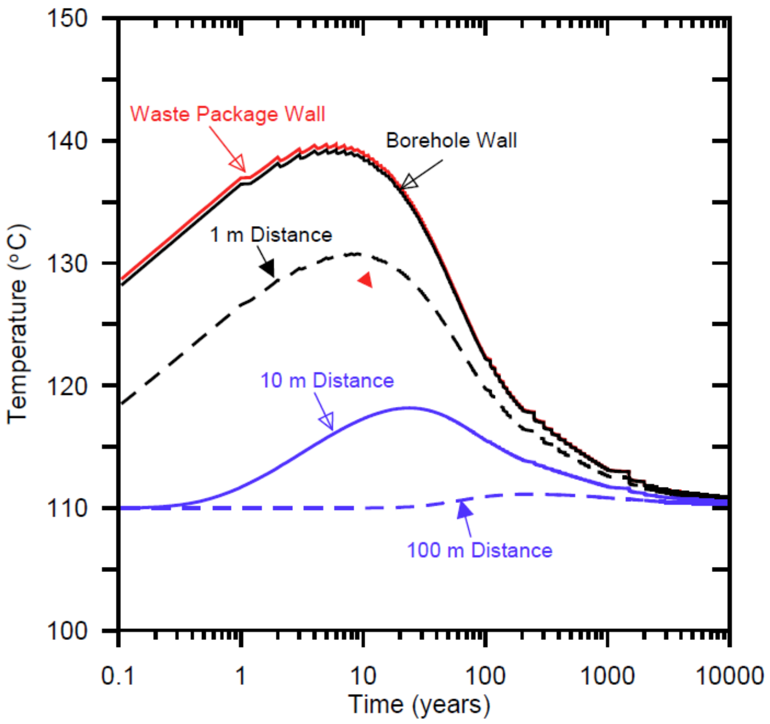
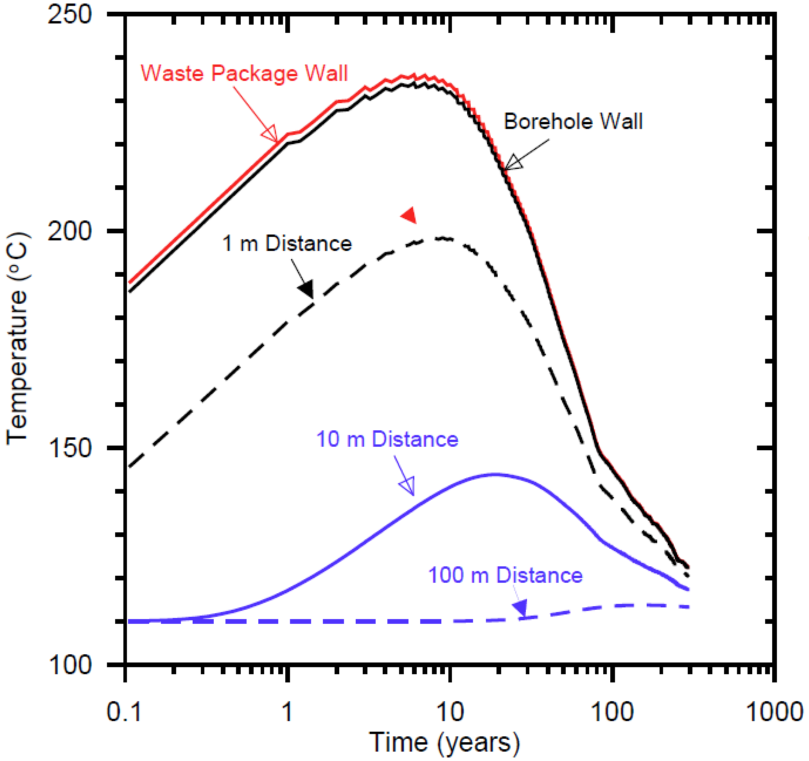


Temperature as a Function of Time and Distance from the Borehole for PWR Spent Fuel Assembly Disposal



Temperature as a Function of Time and Distance from the Borehole for Disposal of Vitrified HLW from Reprocessing.

http://brc.gov/e-mails/August10/Borehole_SAND2009-4401.pdf

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Heat and Salt: Theory and Practice

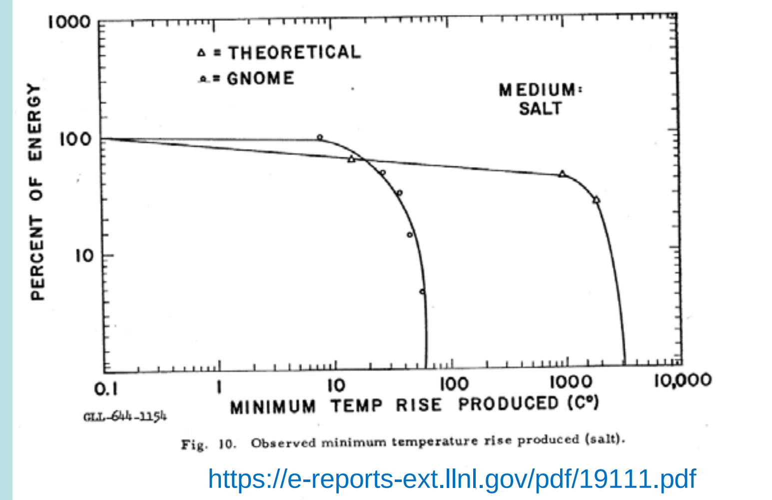
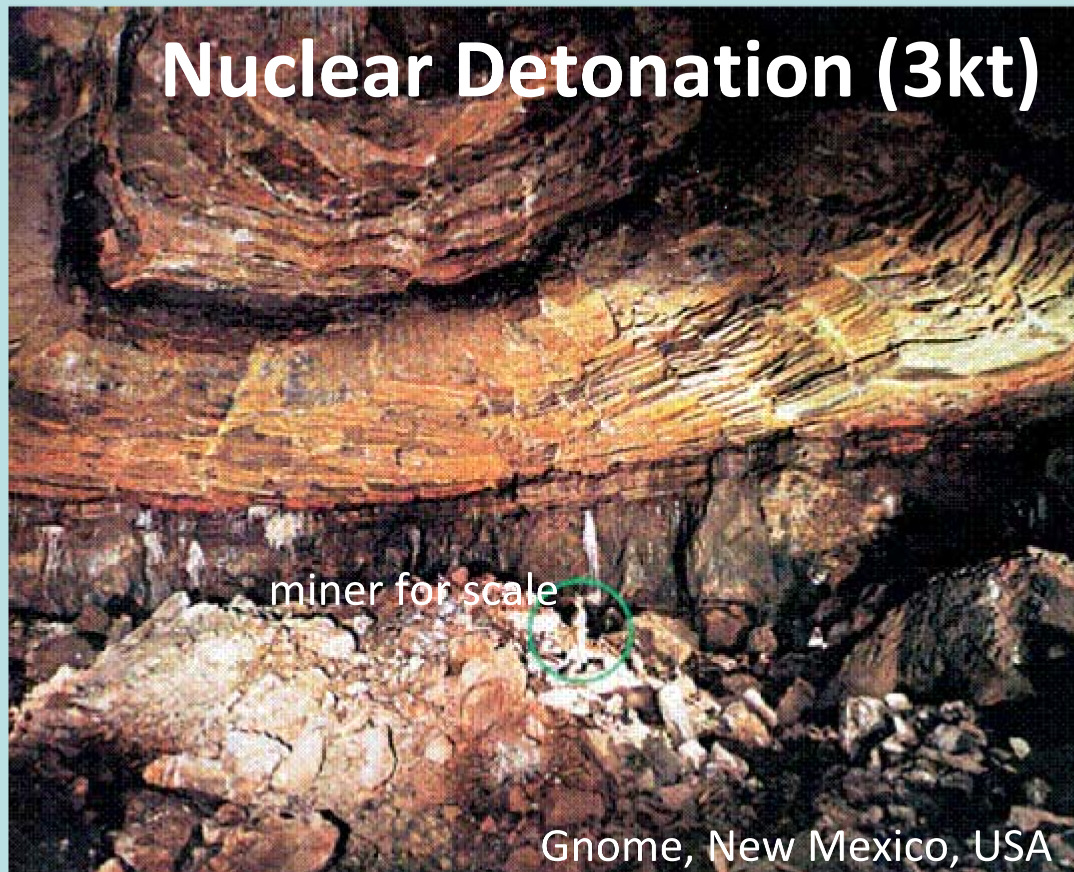


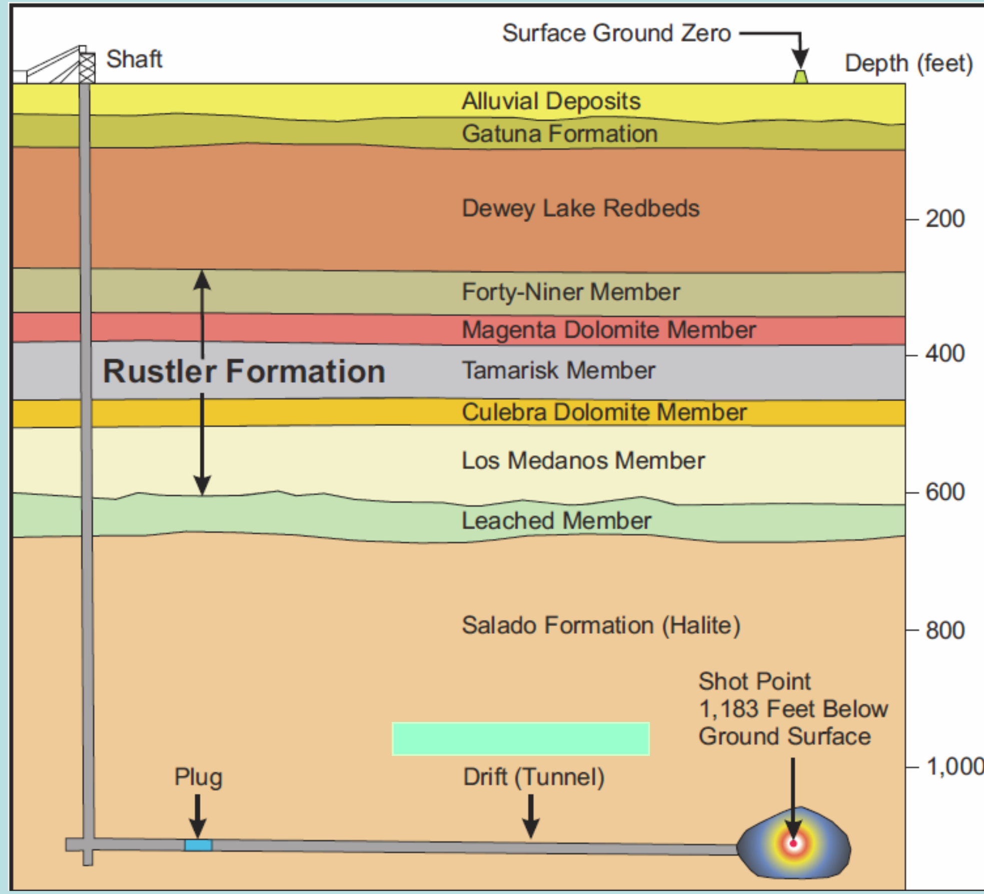
Fig. 10. Observed minimum temperature rise produced (salt).

https://e-reports-ext.llnl.gov/pdf/19111.pdf

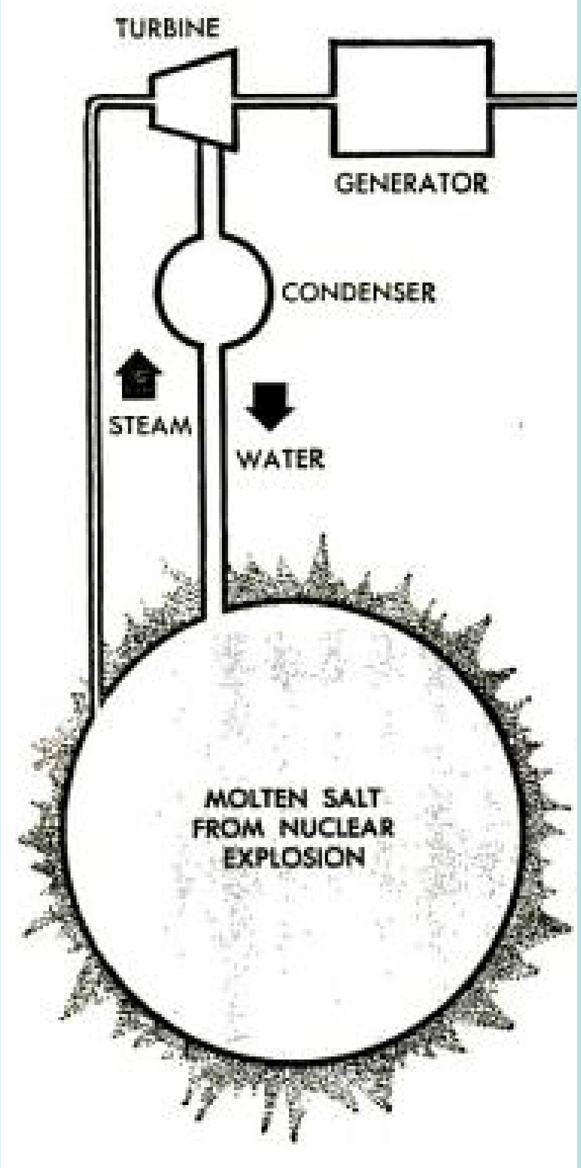
Basalt Dike



Cavity produced by Gnome detonation and subsequent collapse 70 feet high and >150’ across (miner at right center of rubble pile). *Photo by Lawrence Radiation Laboratory*

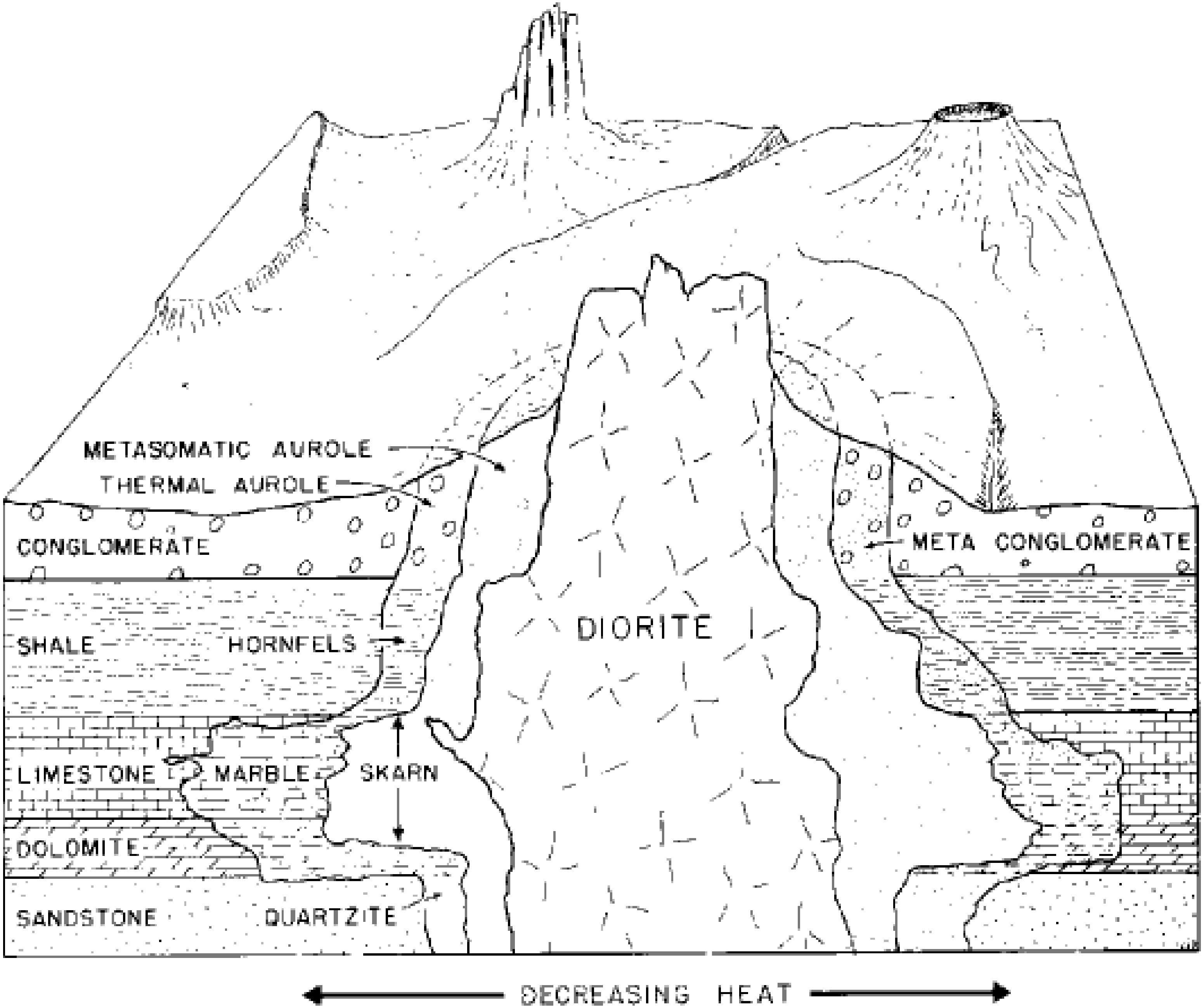


http://www.lm.doe.gov/Gnome/Documents.aspx

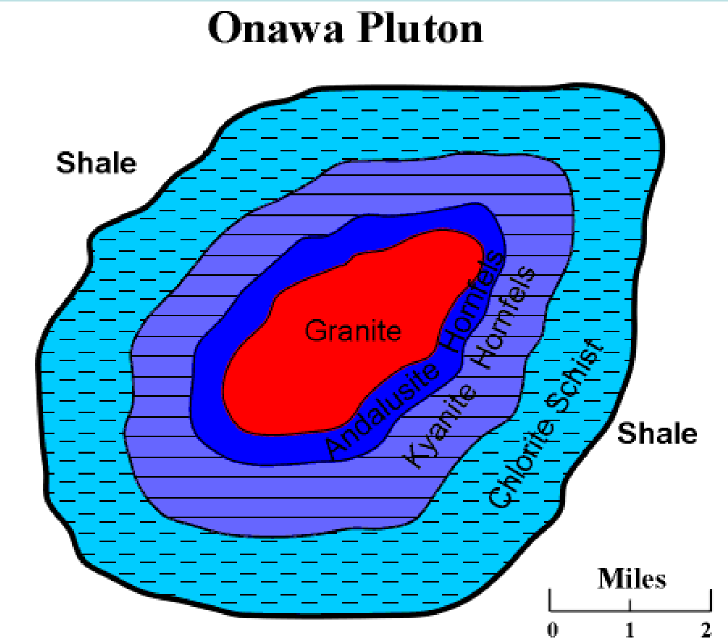


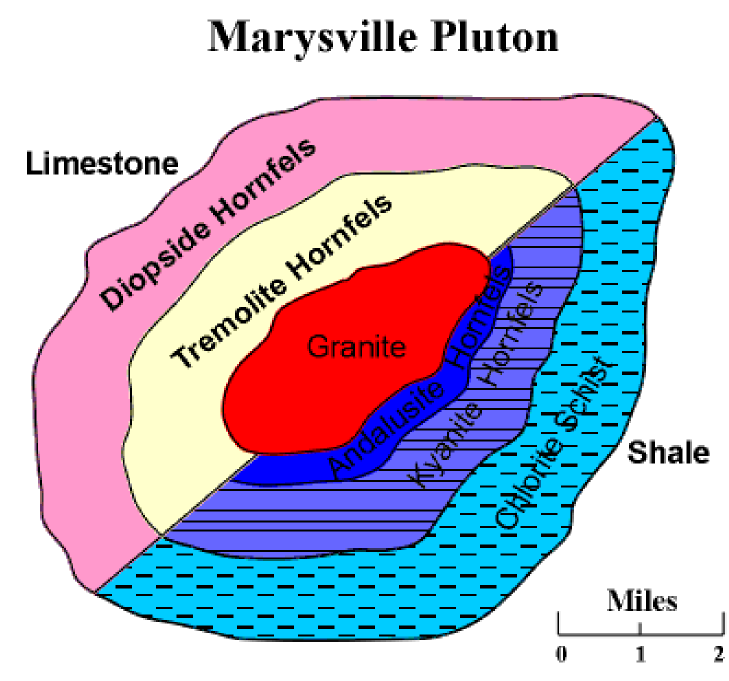
Edward Teller, “We’re Going to Work Miracles”
Popular Mechanics, **113**, 3, p.100, March 1960

http://books.google.com/books?id=v9sDAAAAMBAJ&pg=PA100&lpg=PA100&dq=Gnome,+Plowshare,+AEC&source=bl&ots=CJW8rz9kei&sig=uacAhLB8ik5htr8dyFIwflg7Kpw&hl=en&ei=A7cHTab9BoOcsQPU__CxDg&sa=X&oi=book_result&ct=result&resnum=4&ved=0CC8Q6AEwAzgU#v=onepage&q=Gnome%2C%20Plowshare%2C%20AEC&f=false

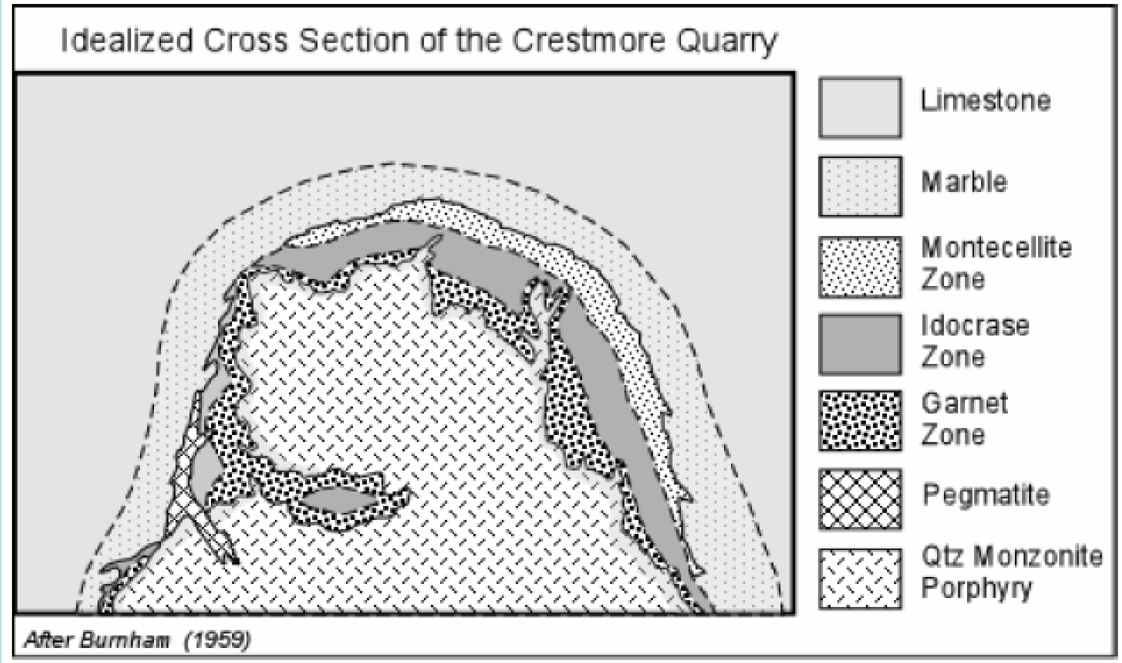


http://csmres.jmu.edu/geollab/fichter/MetaRx/Contact.html





http://geology.csupomona.edu/drjessey/class/Gsc101/Meta.html



Metamorphism and metasomatism produced four zones near the contact, three ranging from 3cm to 15m wide.

http://www.tulane.edu/~sanelson/eens212/contactmeta.pdf

http://www.indiana.edu/~geol105/images/gaia_chapter_5/igneous_rock_bodies.htm

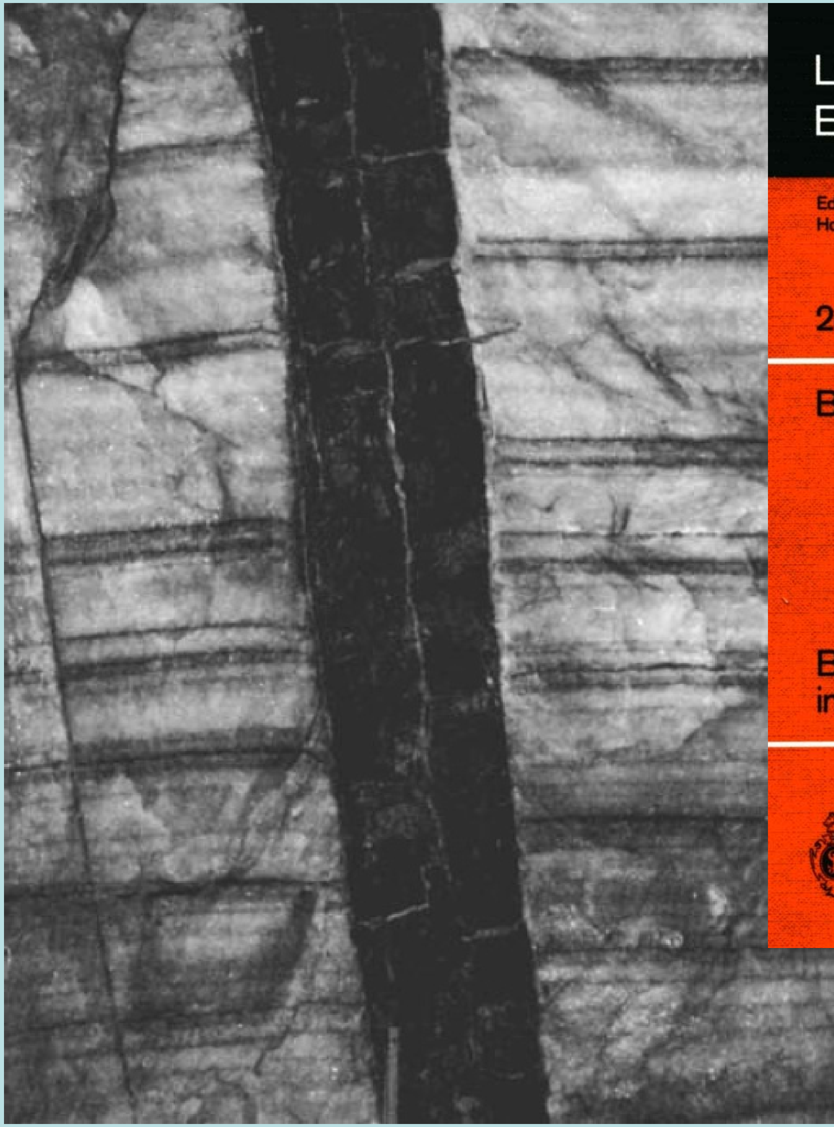
http://www.answersincreation.org/curriculum/geology/images/Dike_Cross-Island_Trail_Alaska.jpg

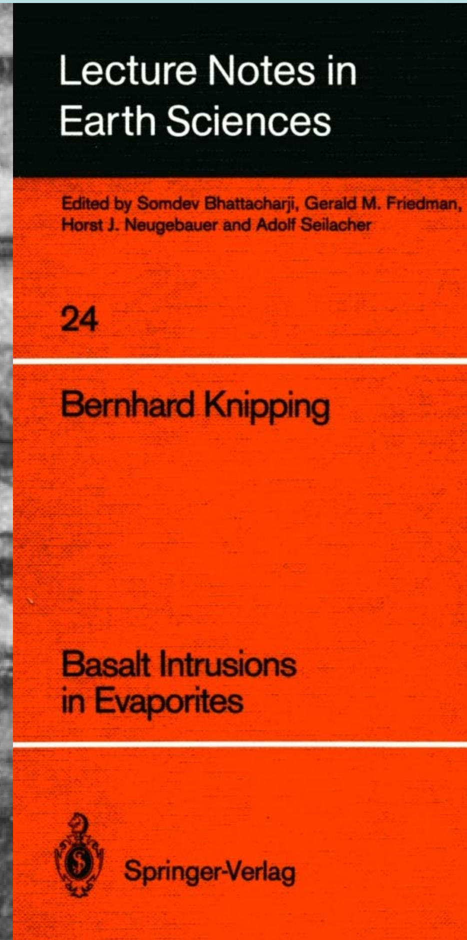
Igneous Dikes

Photos by Brian Penn

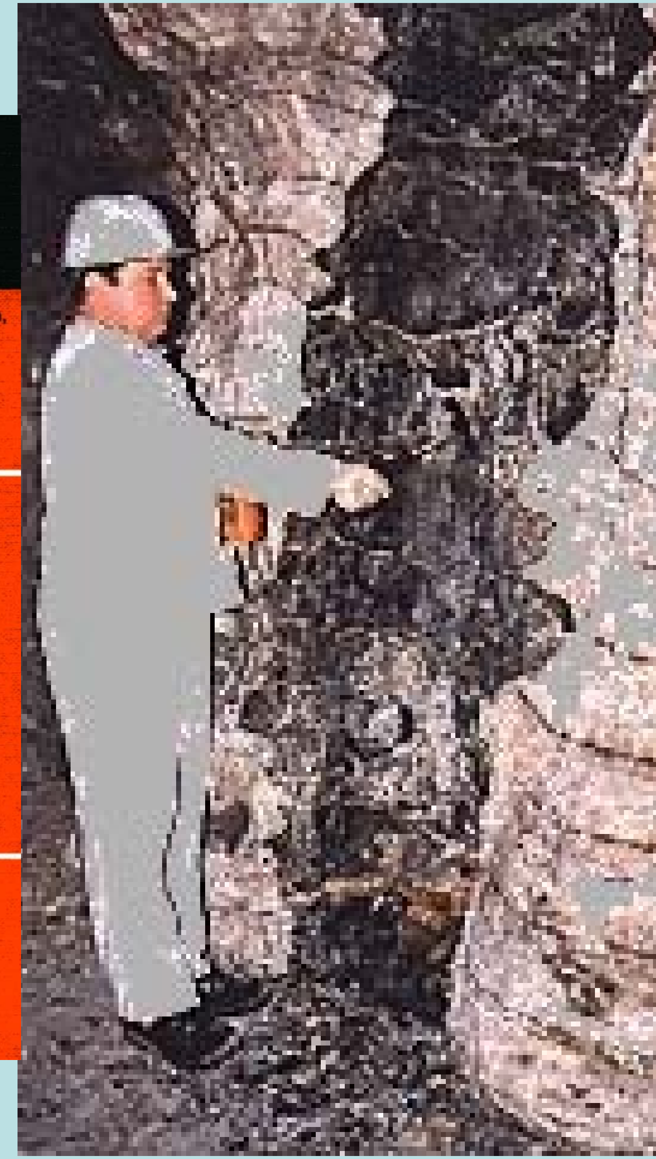
http://www.spanishpeakscolorado.com/

http://www.braaschphotography.com/FabulousPhotos/18ShipRockNM.





1989



Dike in Merkers potash mine

Dike width 30 cm, contact zone <2 cm wide

http://www.oeko.de/oekodoc/858/2008-001-de.pdf

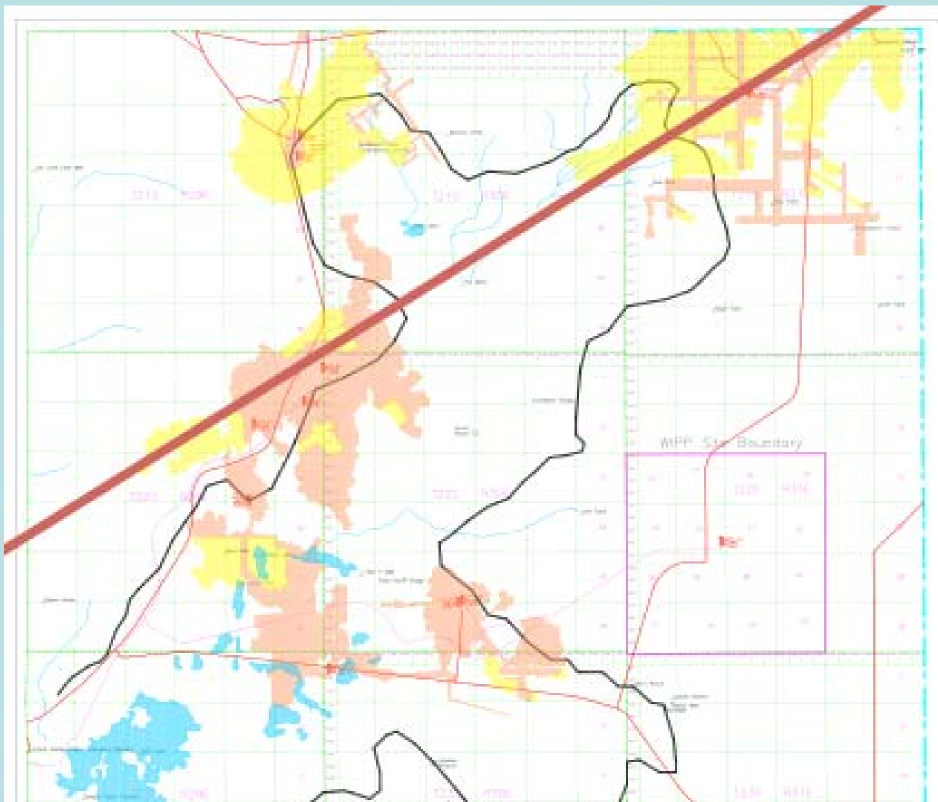
http://literatur.freepage.de/cgi-bin/feets/freepage_ext/41030x030A/rewrite/labonte/geologie/merkers/abb2.htm

Transactions, American Geophysical Union Volume 31, Number 2 April 1950

OBSERVATIONS ON THE INTRUSION OF ROCK SALT BY PERIDOTITE

John G. Broughton

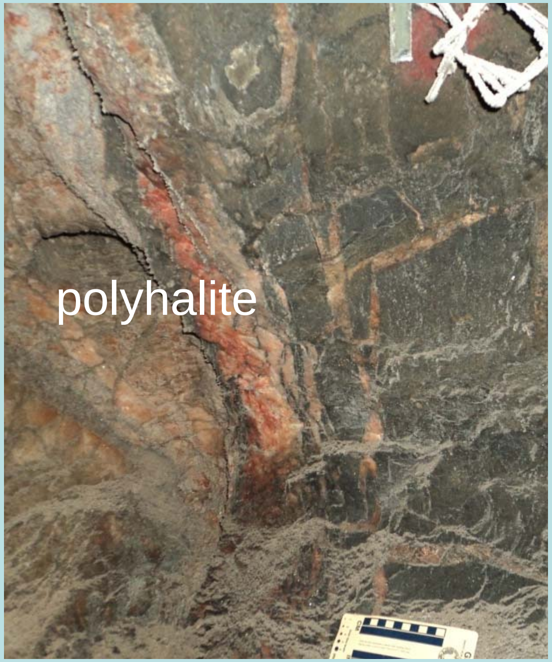
Abstract--One of the narrow peridotite dikes of central New York has been observed cutting rock salt at a depth of 0.4 mile. It follows one of the regional cross joints and is probably post-Appalachian in age. Structural relationships show mutual intrusion of the peridotite and salt and suggest that the temperature of the tenuous igneous magma only slightly exceeded the melting point of the halite.

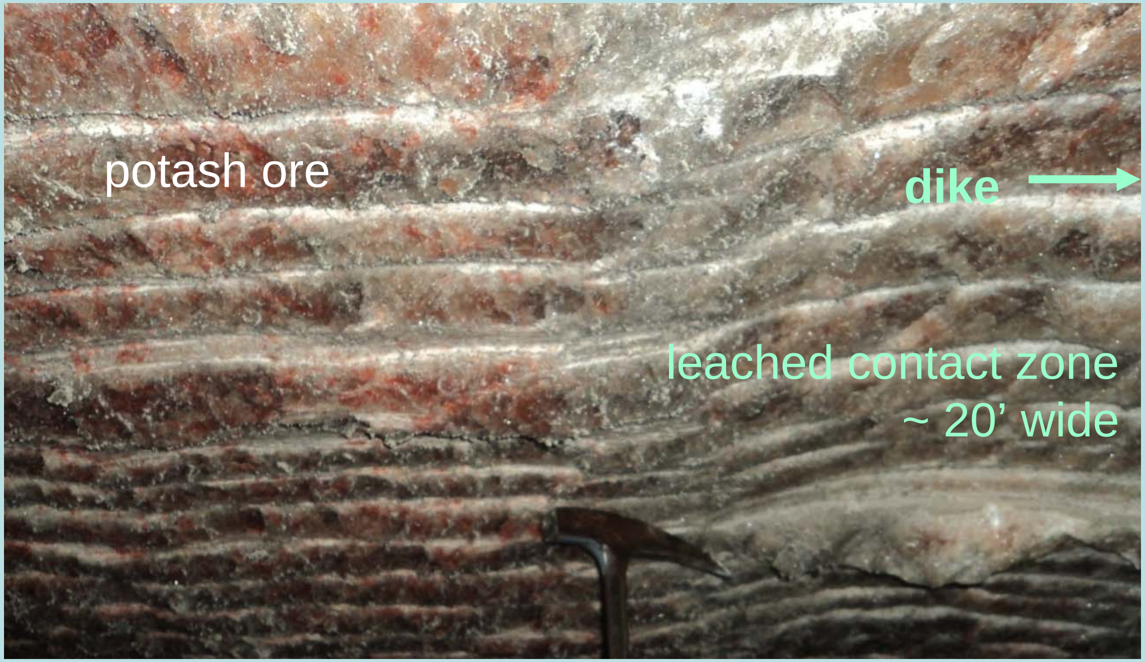


enhanced from DOE illustration

Approximate dike trend through Carlsbad potash mines (Mosaic and Intrepid)

Salt and peridotite samples from Cayuga mine (courtesy Leo Van Sambeek)





Igneous dike in Intrepid potash mine, Carlsbad, NM

http://www.texashuntworks.com/index.php/Media/Pictures/Moose-Stuck-In-A-Rut.html

General Caution

1. Presentations are open to misinterpretation without (or likely even with) the presenter's interaction with his audience.
2. Data, ideas, and conclusions that are extracted may be in error outside the original context or intent.
3. The presenter or provider of this material is not liable for inappropriate or erroneous use of the material or its consequences.
4. None of the material should be assumed to be be original.

Special Note

Norbert T. Rempe prepared this presentation as a private individual, not for profit. This work was *NOT* sponsored by any private organization or government agency.

Auxiliary slides

UNDERGROUND NUCLEAR TESTS AND OTHER WORST-CASE ANALOGUES FOR GEOLOGIC WASTE ISOLATION

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Six nuclear underground detonations in New Mexico, Colorado, and Louisiana provide useful anthropogenic analogues for geologic isolation of dangerous wastes. All resulted in negligible or undetectable harm to humans and their environment. Nature provides other worst-case analogues such as magmatic intrusives and their very thin metamorphosed contact zones. These extreme examples add to the already very reasonable confidence that geologic media can confine dangerous substances safely and permanently.

Geologic Disposal – Technical Challenges

- Waste isolation is challenging because inventories and properties of the waste vary widely
- Heat generated by the waste affects geochemical processes and the rates of degradation of engineered barriers
- Result is a dynamic and complex repository system
- Extensive modeling is necessary to predict repository performance

The fascinating impressiveness of rigorous mathematical analysis, with its atmosphere of precision and elegance, should not blind us to the defects of the premises that condition the whole process (T. C. Chamberlin, 1899)

http://brc.gov/pdfFiles/November2010_Meeting/GarrickBRCSlides111610.pdf

83% of present surface heat flow is due to radioactive decay of U, Th, and K

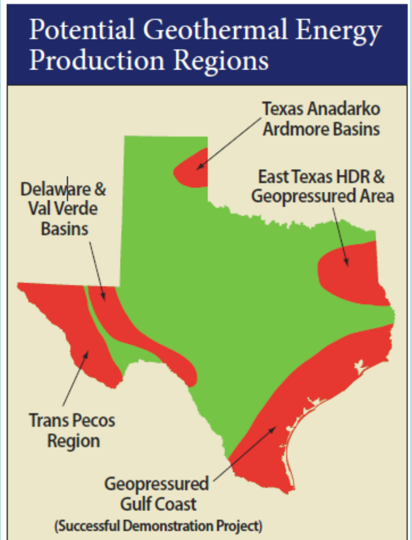
http://www.und.edu/org/ihfc/Gosnold_AAPG07.ppt#316,18,Global Heat Flow

Geothermal energy is the ethical energy source for the future

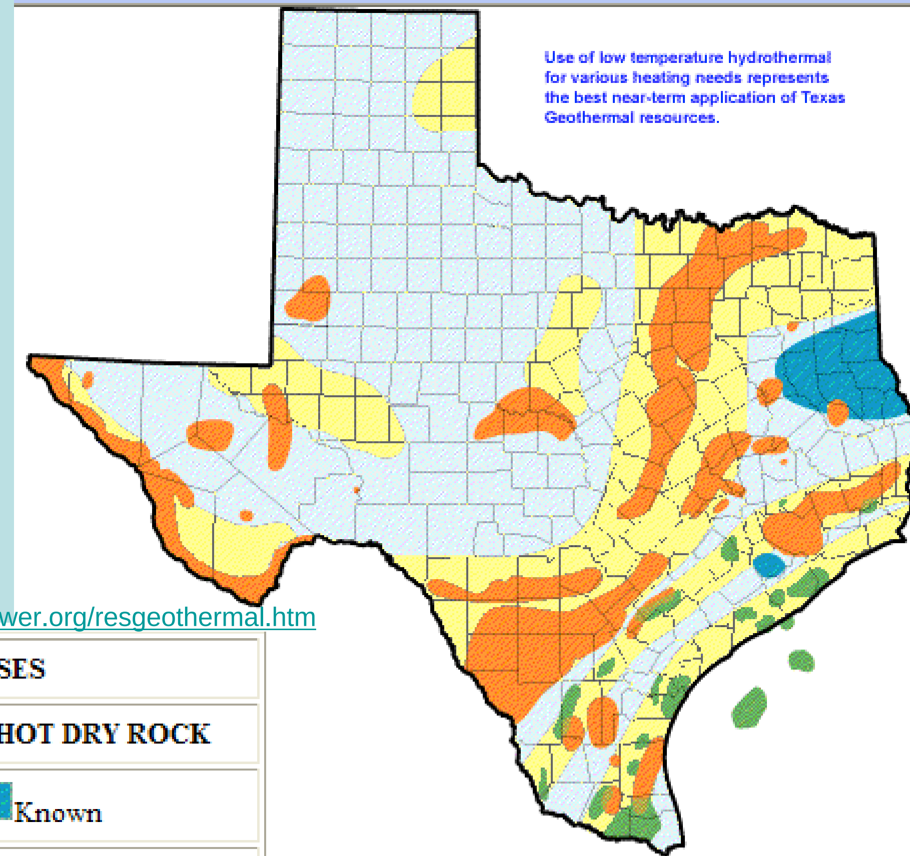
http://www.heatflow.und.edu/Gosnold2Geothermal.ppt#263,1,Geothermal Energy is the Ethical Energy Source for the Future

Geothermal resources are
low temperature (< 90°C or 194°F),
moderate temperature (90°C - 150°C or 194 - 302°F), and
high temperature (> 150°C or 302°F)

http://geoheat.oit.edu/whatgeo.htm



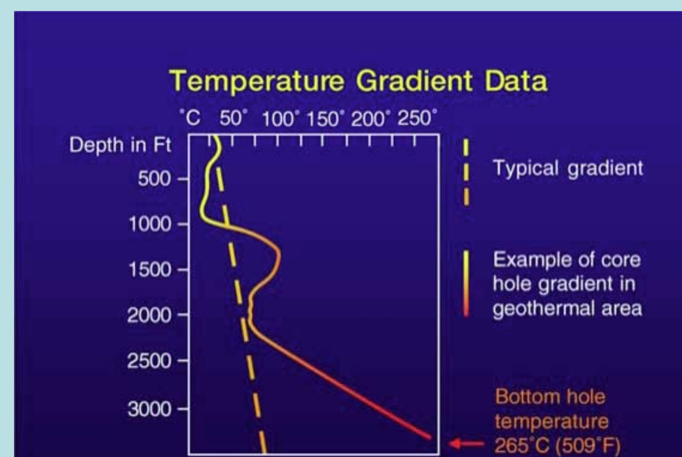
http://www.window.state.tx.us/specialrpt/energy/pdf/21-Geothermal.pdf



http://www.infinitepower.org/resgeothermal.htm

TEXAS GEOTHERMAL AREAS, CHARACTERS AND USES

	HYDROTHERMAL	GEOPRESSURE	HOT DRY ROCK
AREAS	Known (orange)	Known (green)	Known (blue)
	Potential Hydrothermal or Geopressure Source (yellow)		
CHARACTERISTICS	• 90 - 160 °F Water (500-5,000 ft. deep) • In some cases Water is Potable	• 300 - 450 °F Brine (>13,000 ft. deep) • High Pressure • Dissolved Methane	• Gradient >45 ° C/km • Little or No Water
USES	• Space Heating • Fish Farming • Desalinization • Resort Spas	• Heating • Enhanced Oil Recovery • Electricity	• Heating • Electricity



http://geothermal.marin.org/GEOpresentation/sld030.htm

Key assumptions:

Conduction only in dry rock

$Width_{dike}$	100m
$T_{magma, initial}$	1 100°C
$T_{host rock, initial}$	0°C
$T_{heat of latent crystallization}$	1 100-800 °C

Calculated results:

$T_{solid dike}$	800°C after 10 300a
$T_{host rock}$	600°C after 1 600a

Model assumes that all heat moves by conduction. If country rock is saturated with water or pluton expels water, and if country rock is permeable, then heat will move into country rock by convection. Water will be heated near contacts and carry heat outward and away where it will eventually cool to return to contacts to carry away more heat.

http://www.tulane.edu/~sanelson/eens212/contactmeta.pdf

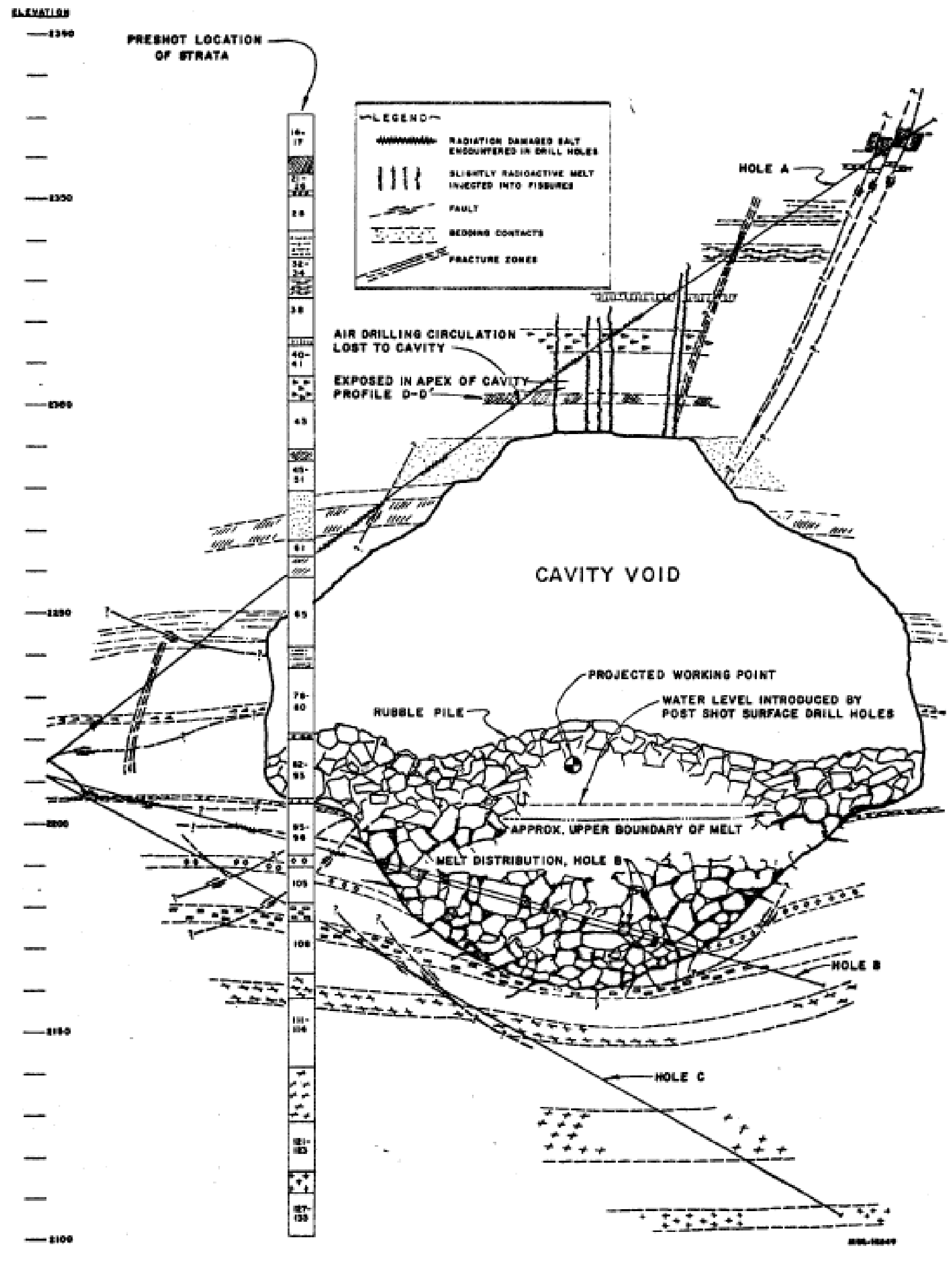
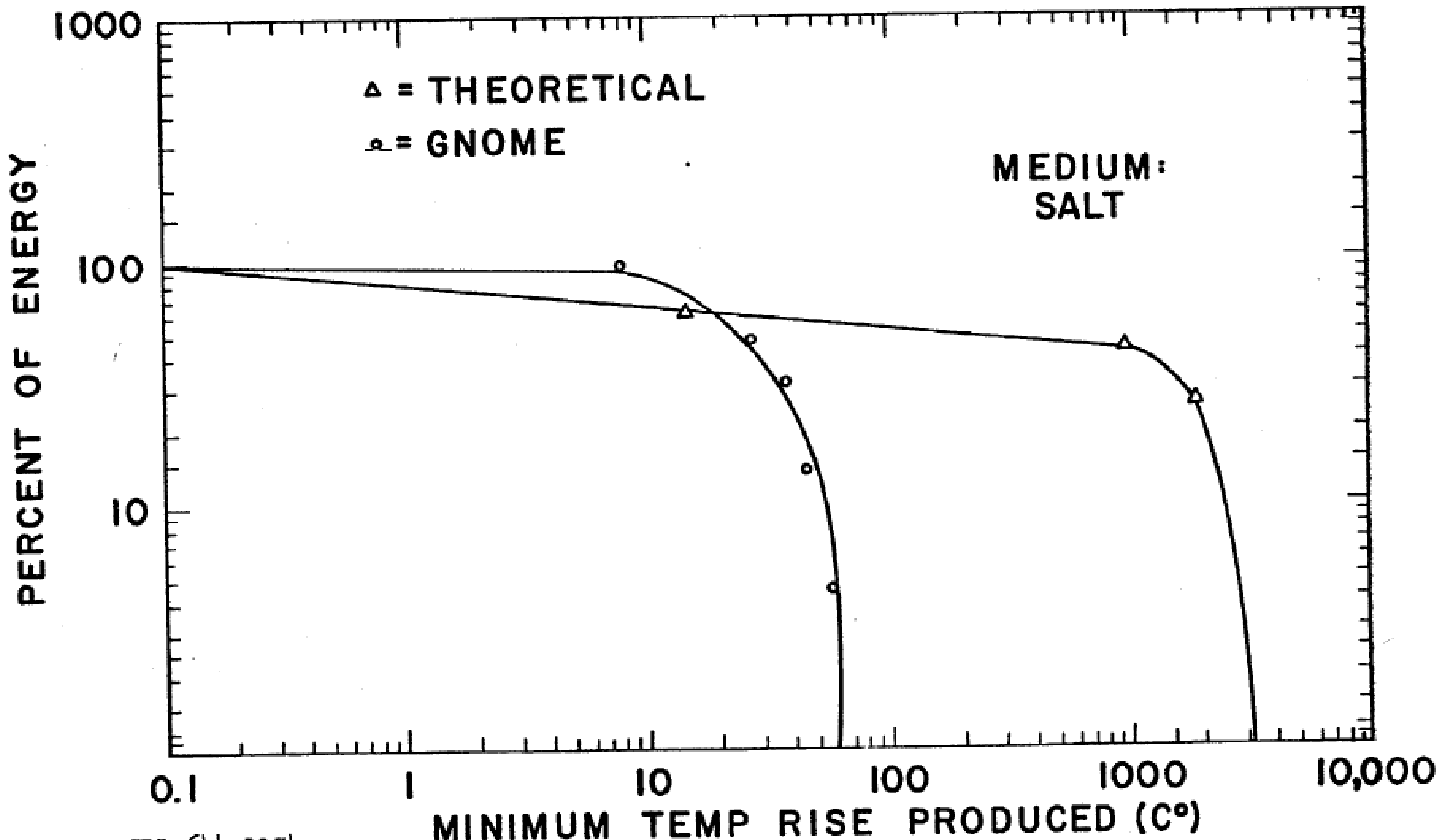


Fig. 14. Gnome cavity profile.



GLL-644-1154

Fig. 10. Observed minimum temperature rise produced (salt).

Liquid Russian Waste Injection

Table I. General characteristics of liquid radioactive wastes

Type of wastes	Specific activity, Ci/l	Macrocomposition
Non-technological LLRW	10^{-8}-10^{-5}	Salt content 1-30 g/l ($NaNO_3$, hardness salts), pH 8-10
Technological ILRW	10^{-5}-1	Salt content to 300 g/l ($NaNO_3$, sodium aluminate, NaOH)
Technological HLRW	0.1-10	Salt content to 250 g/l ($NaNO_3$, soluble complexes of corrosion products), pH 2-3

Table II. Content of radionuclides in disposed wastes

Radionuclides	Content, %		
	HLRW	ILRW	LLRW
^{90}Sr, ^{137}Cs	7.5-30	50-56	50-70
^{144}Ce, $^{103,106}Ru$, ^{95}Nb + ^{95}Zr and so on	92.5-70	50-44	50-30

By now, wastes with activity of ~2,100 MCi were disposed at all three sites.

source: I.M.Kosareva et al. (2001) http://www.wmsym.org/archives/2001/31B/31B-19.pdf

Since 1960 about 50,000,000 m^3 liquid waste with an activity of about $3x10^{19}$ Bq were injected into deep porous layers at the sites Tomsk-7, Krasnoyarsk-26 and Dimitrovgrad.

source: Schneider & Herzog (2000), IAEA-CN-78/9 http://www.bvsde.paho.org/bvsacd/safety/paper009.pdf

It should be noted that discharges to the (*Yenisei*) river are not the only releases to the environment at this (*Krasnoyarsk-26*) site. Eleven EBequerels (300 million curies) have also been injected underground.

source: Frank L. Parker et al. (1999) http://www.wmsym.org/archives/1999/56/56-6.pdf

History and Overview of Deep Injection of Radioactive Liquids in Russia

A.I. Rybalchenko, V.M. Kurochkin, A.A. Zubkov, GWPC Annual Forum, 2004

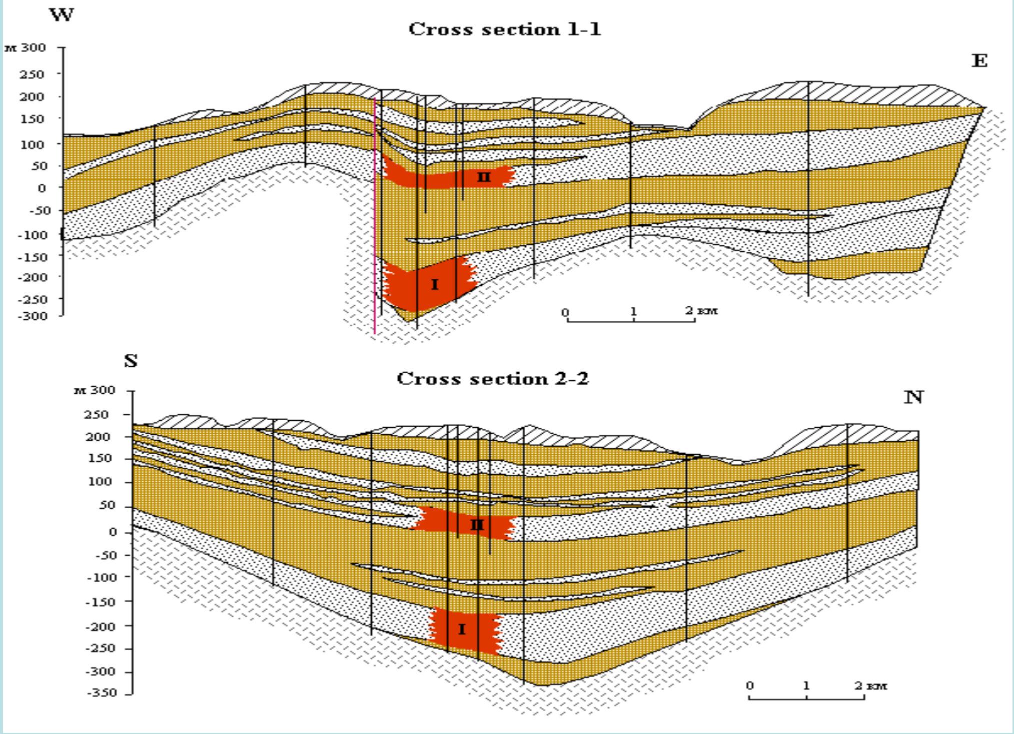
The main results of injection:

During last 40 years more than 50 million cubic meters on radioactive wastes were injected within 3 injection sites

10 million cubic meters of toxic waste were injected within 2 injected sites

Thus the negative impact of this waste on environments and population was prevented

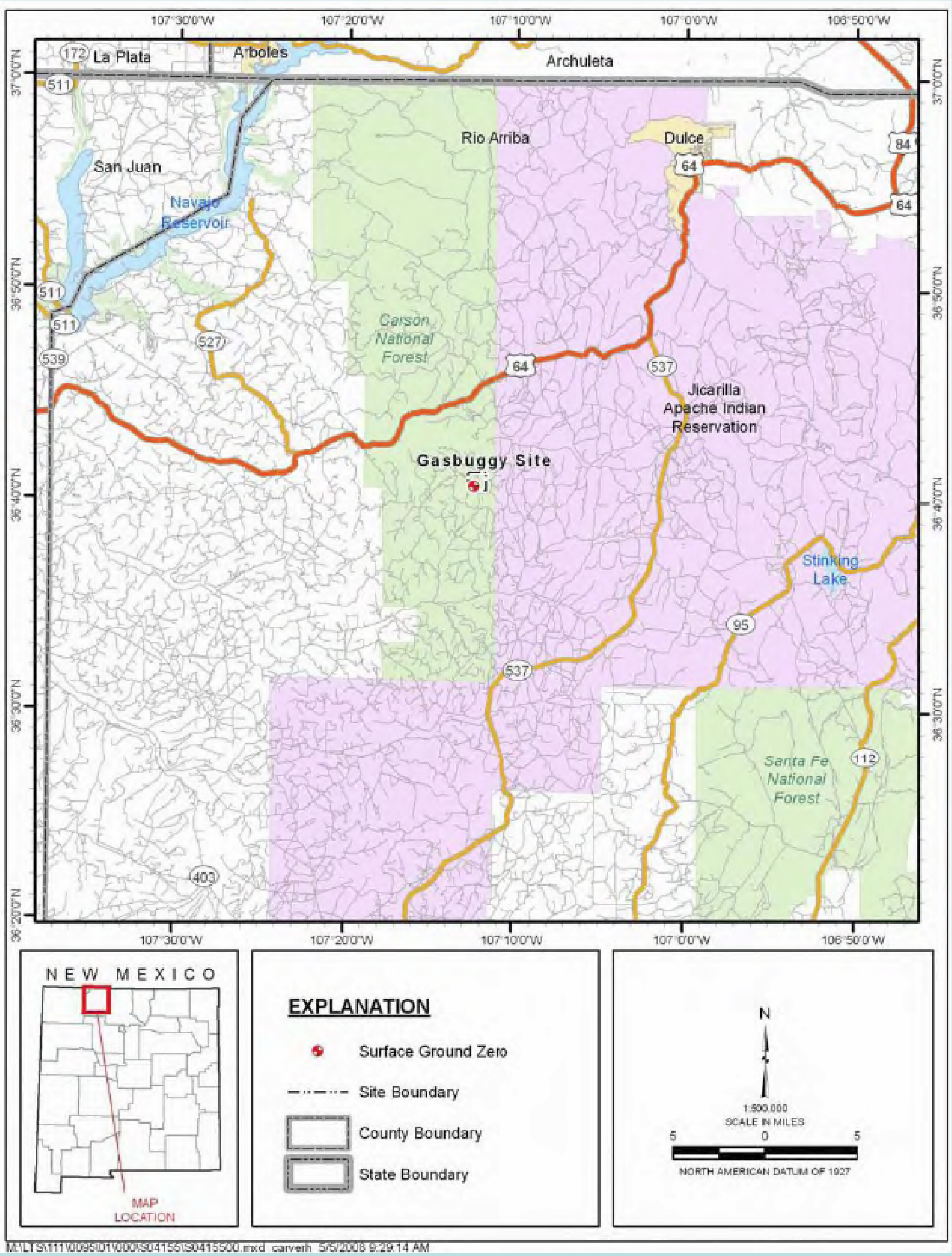
BORehole **I**njection **S**ites at Krasnoyarsk-26 and Tomsk-7

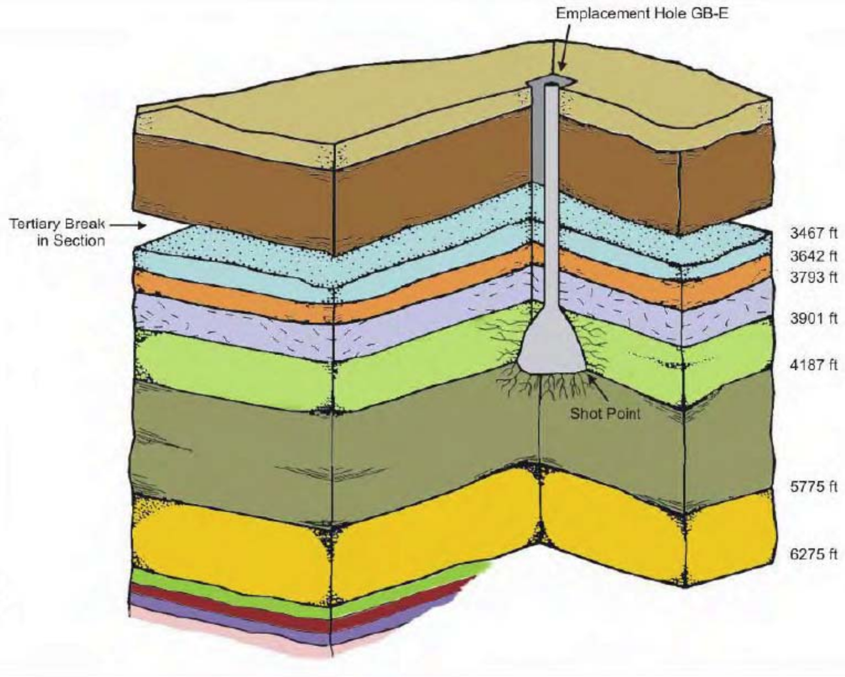


DEEP WELL INJECTION SITES FOR RADIOACTIVE AND NON-RADIOACTIVE WASTE OF MINATOM ENTERPRISES

Enterprise	*Type of waste*	*Injection depth, m*	*Injection start*	*Injected waste million m^3*
SCC (Tomsk-7)	Liquid radioactive	270-320 314-386	1963	45
MCC (Krasnoyarsk-26)	Liquid radioactive	180-280 355-500	1967	6.0
SCC NIIAR Dimitrovgrad	Liquid Radioactive	1110-1350 1420-1510	1966	2.6
ChMZ (Glasov)	Non-radioactive Natural nuclides	1420- 1540	1992	5.2
K-Chp Combine (Kirovo-Chepetsk)	Non-radioactive (fertilize production)	1300 - 1400	1987	4.1
Kalinin NPP	Non-radioactive Tritium solution	1200 - 1400	2005	-

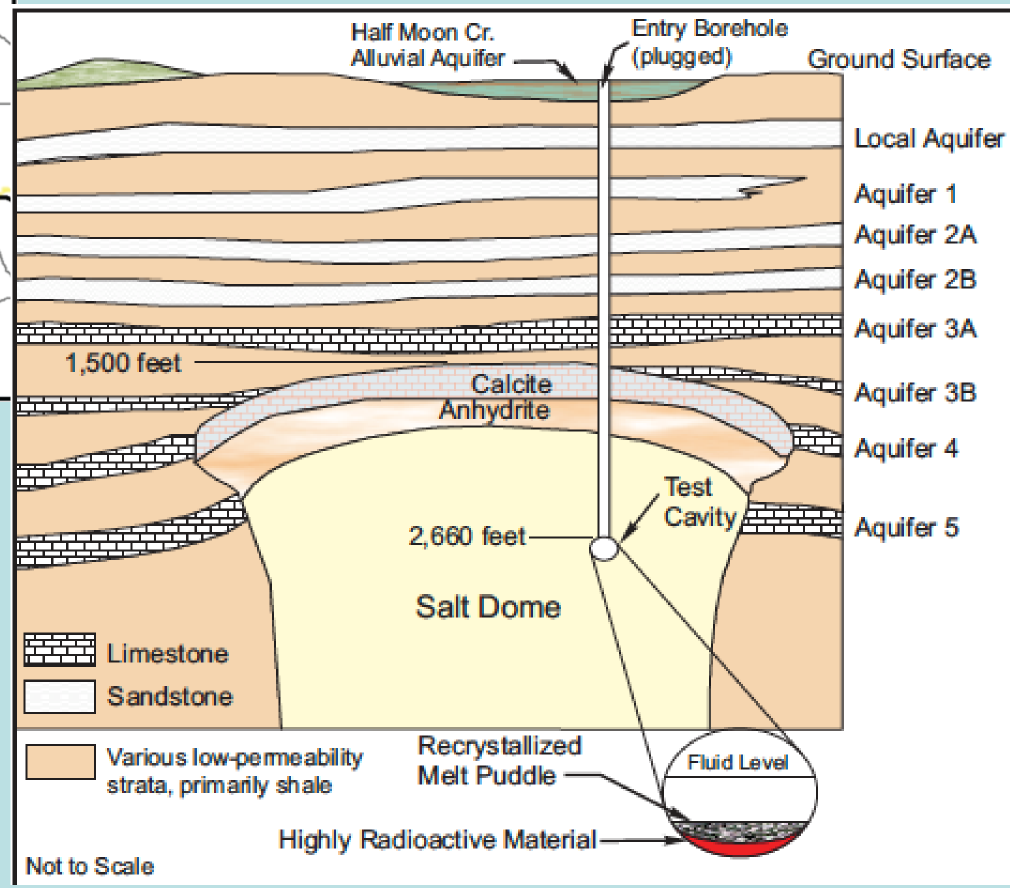
Gasbuggy/Plowshare





www.lm.doe.gov/Gasbuggy/S04019_GSB.pdf

Mississippi test location



	kt	
Salmon:	5.3	Oct. 1964
Sterling:	0.38	Dec.1966
Diode Tube	0.315	Feb.1969
Humid Water	0.315	April 1970

*nuclear *CH_4/O_2 explosive

www.lm.doe.gov/WorkArea/linkit.aspx?LinkIdentifier=id...1325

Thank you for giving me the opportunity

to make your minds play

“outside the box”