Exploration and discovery of blind breccia pipes - the potential significance to the uranium endowment of the Arizona Strip District, Northern Arizona

Eugene D. Spiering
VP Exploration
The Last Hard Rock Uranium Producer in the U.S.

- 1000 sq miles in Colorado Plateau Province of NW Arizona
- From 1980 to 1990, Energy Fuels Nuclear produced 19 million lbs of $U_3O_8$ from 7 breccia pipes
- Average grade of 0.64% $U_3O_8$ places these deposits among the highest grade in the U.S.
Why the last hard rock uranium producer in the US?

High grades and small mines

- Short development time: 3 yrs from discovery to mining
- Small footprint: mine complex < 20 acres
- Easy reclamation: waste pushed back in mine shaft and surface reclaimed

Exploration and development is quick
Production is clean and economical
Reclamation can be nearly perfect

Economical

- High Grades, no ground water
- Excellent rock conditions
- “Cookie Cutter” permitting, mine design and development

Reclaimed Hack Canyon Mine
Reclaimed Pigeon Mine

Quaterra Resources Inc.
Northern Arizona Strip Uranium Deposits

Historically defined reserves and resources of 27 million pounds $U_3O_8$ in 15 breccia pipes

(1.8 million lbs $U_3O_8$ per pipe)

- Reserves/production
  - M lbs $U_3O_8$ / # pipes
  - 7 Mineralized
- 6 Barren
- 6 under exploration
Arizona Strip Stratigraphy

Depth (ft)

0
500
1000
1500
2000

The Permian section is visible near the Hack Canyon Mine
Breccia Pipe Morphology

- Collapse Cone (due to depletion of evaporites in Pt and Pkh)
- Pipe Throat (area of breccia displaced downward in the pipe-200ft-500 ft)
- Pipe-in-Pipe (secondary collapse adds 300-500ft additional vertical displacement-post mineral)
- Hermit Benches (bounded by ring fractures)
Breccia Pipe Mineralization

U source is believed to be volcanic ash of the Late Triassic Chinle Formation transported by groundwater in the Coconino Ss. (Ludwig and Simmons, 1992)

Coconino Ss acts as conduit for U mineralization and host as Ss dominant breccia in pipe

Pyrite Cap (py after marcasite) <50 ft thick

Coconino Ss dominant breccia hosted U mineralization

Ring fracture hosted U mineralization

- U occurs as pitchblende.
- Calcite and gypsum are cementing minerals.
- Trace elements include Cu, As, Ni, Pb, Zn and Ag.

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Breccia Pipe Exploration

Surface geological mapping and surface TEM defines a target

Shallow drilling locates the pipe throat within collapse cone

**Down-hole Gamma-Ind-Neutron and Dev logs (Strata Data, Casper Wyo.) allow dry hole definition of lithologic dominance and sulfides in breccia**

Deep drilling guided by borehole TEM defines the orebody

**15-20 foot spot core taken at 200’ intervals gives lithologic control for log correlations**
Breccia Pipe Surface Expression

- Kanab N.
- Kanab S.
- Pigeon
- Clearwater
- Hermit
- Findlay Tank N.
- Findlay Tank S.
- Ollie
Sunshine Breccia Pipe - Barren

Some pipes collapse too much

- One of the largest vertical displacements of breccia in pipes of the northern district
- Outcrops of Upper Triassic Shinarump ss visible in the center of a collapse cone in near the top of at Pkfm
- < 1200 feet of vertical displacement

- Drilled to a depth of 1,580 feet – barren
- Favorable Coconino Ss dominant breccia horizon has probably dropped to into the Redwall Ls. and well below economic potential.
Blind Pipe Geometry

Other pipes don’t reach the surface

- Blind pipes may potentially be larger deposits
- Hack 2 (7 million lbs $U_3O_8$) did not reach the surface and is the largest deposit ever found in the district
- Absence of subsequent internal collapse may stop upward growth and prevent downward displacement of the mineralization.
**Hack 2 Pipe**

- Unbrecciated upper Kaibab outcropping at surface.
- Located within a mile wide area of evaporite-depleted Toroweap and Kaibab section.

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**A Blind Breccia Pipe**

- Discovered in 1979 by Western Nuclear.
- Fe staining in Coconino and altered Hermit shale in Hack Canyon.
- Alteration including secondary gypsum and other sulfates at Coconino/Hermit contact.
### Gump Pipe

**Well defined and dated upper limit of stoping**

- 4000 ft diameter collapse cone
- Pipe throat did not reach the surface.
- Stoping terminated in late Permian.
- Bimodal sandstone filled pipe throat prior to evaporite dissolution

- Dome centered over the pipe throat
- Drilled to a depth of 2240 feet
- Pipe in pipe (secondary collapse) scattered U mineralization to TD
Arizona Strip Airborne VTEM Survey

First extensive test of airborne time domain EM on the Strip

- Geotech Airborne surveyed 422 square miles
- 150 m line spacing
- 30 m AGL
- Most known pipes detected
- > 200 high to mod. priority anomalies with similar signatures
**A-1 Anomaly**

- Beautiful geophysical anomaly at A-1 but no collapse cone or throat visible at the surface.

- First shallow drill hole encountered 15 ft of massive gypsum in upper Toroweap section.

- Subsequent drilling defined a blind pipe 500 ft to the north.
A-1 VTEM Response – Plan and Section

Inversions and depth slices by Condor Consulting, Denver Colorado using the raw VTEM data

Red is conductive

Moenkopi Fm.
Kaibab Fm.
Toroweap Fm.
Coconino Ss.
Hermit Shale
Esplanade Ss.

Conductivity Depth Slice 1217-1414 ft

2D Conductivity Section

Quaterra Resources Inc.
A-1 Pipe

A New Blind Pipe

No structure within 500 ft of the surface-undepleted evaporite section in the Harrisburg

Sulfides cementing small clast is dominant bx at base of Pkfm.

Small clast dissolution breccia in Toroweap.

Disseminated sulfides near Pc/Ph contact above the pipe throat.

Hole A1-31 intercepted 28' av. 0.58% eU3O8 at 1046’ and 4' av. 0.45% at 1119’ in upper Hermit

Hole A1-30 still in large clast Hermit dominant breccia at 1500’

No secondary pipe in pipe structure evident
Breccia Pipe VTEM Response 150usec Conductivity

• 2 known pipes: Gump and Ollie

• A-1 blind breccia pipe discovered on first VTEM anomaly drilled (First new mineralized breccia pipe identified in 18 yrs)

• Drilling at A-18 and A-21 defined probable pipe structures with up to 40 ft of closure in the upper Kaibab horizon.

Mineralized pipe discovered at A-20 second VTEM anomaly drilled
A-20-1: 34.5 ft @ 0.37% incl. 6.5 ft @ 0.63% U₃O₈
AIRBORNE VTEM SURVEY – Gump Model 17-25 m

All depths in meters

Gump BX Pipe Diagrammatic X-Section

Watch Depth Arrow

Pipe Center

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AIRBORNE VTEM SURVEY – Gump Model 25-34 m
AIRBORNE VTEM SURVEY – Gump Model 55-68 m
AIRBORNE VTEM SURVEY – Gump Model 120-143 m
AIRBORNE VTEM SURVEY – Gump Model 169-199 m

Gump BX Pipe Diagrammatic X-Section

- Moenkopi
- Kaibab
- Toroweap
- Coconino
- Hermit
- Esplanade

Depth (m)
AIRBORNE VTEM SURVEY – Gump Model 243-273 m
AIRBORNE VTEM SURVEY – Gump Model 273-319

Gump BX Pipe Diagrammatic X-Section

- Moenkopi
- Kaibab
- Toroweap
- Coconino
- Hermit
- Esplanade

Sulfide cap conductivity anomaly?
AIRBORNE VTEM SURVEY – Gump Model 431-500 m

Gump BX Pipe Diagrammatic X-Section

Depth (m)

- Moenkopi
- Kaibab
- Toroweap
- Coconino
- Hermit
- Esplanade

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AIRBORNE VTEM SURVEY – Gump Model 580-673 m
Breccia Pipe Density

The USGS Open File Report (OFR-89-550) shows the mapped locations of 1,296 pipes in the Grand Canyon region.
Breccia Pipe Density Log-Log Plot

How many mineralized pipes in the N district?

What is the potential of the N district?

@ 3,200 feet of sedimentary cover (Lower Toroweap horizon) ~ 12 pipes per 100 square miles

1000 square miles in the northern district X 12 pipes/100mi² = 120 pipes

120 pipes X 1.8 million lbs/pipe = 216 million lbs

= 108 tons U3O8/sq. mile
Based on the Hack–Pinenut Control Area, favorable Areas A and “Ab” were given a calculated mean endowment of **112.4 tons** U₃O₈ per square mile.

- All of the northern district is included in this category
- The same endowment was given to the southern Arizona Strip district.

A New Phase of Exploration in a Mature District

Conclusions

• Airborne VTEM has identified most known pipes and 200 high and moderate priority conductive anomalies with a similar geophysical response

• Many of these anomalies could be blind pipes

• If just ½ of the anomalies are mineralized pipes, the northern district could attain the USGS endowment estimate of 112.4 tons / sq. mile

• Although individually pipes are small deposits, collectively they may represent more than 200 million lbs U3O8 in the northern district alone

• The southern district could have a similar endowment

• A single mine can produce from several pipes and collectively, the breccia pipes of northern Arizona Strip could achieve a “large” deposit status on a world scale.

• High Grades, no ground water, excellent rock conditions and “cookie cutter” permitting, mine design and development may also rank the Arizona breccia pipes among some of the world’s most economical ore deposits.
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Data Processing – Condor Consulting, Denver, CO
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Borehole and surface TEM - Zonge Engineering, Tucson, AZ

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