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

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Introduction

- Uranium exploration and mining history of the Northern District
- Collapse breccia pipe geology and the application of recent exploration technology
- Uranium endowment estimates and mineral potential of the district
- Current political landscape and congressional actions
- Possible future energy and economic impacts of development
Arizona Strip Uranium District - Introduction and Location

**One of the youngest uranium districts in the US**

- Uranium was originally discovered in 1951 at the Orphan (Cu) Mine on patented claims signed by Teddy Roosevelt in 1906 (3 years before the GC became a national Monument).
- Became a district with a uranium discovery at Hack Canyon in 1978.
Northern Arizona Strip Uranium District

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$_3$O$_8$ from 7 breccia pipes
- Average grade of 0.64% U$_3$O$_8$ places these deposits among the highest grade and most profitable in the U.S.
Why the last hard rock uranium producer in the US?

**High grades and small mines**

- Exploration and development is quick
- Production is clean and economical
- No ground water
- Excellent rock conditions
- “Cookie Cutter” permitting, mine design and development
- Reclamation can be nearly perfect

Reclaimed Hack Canyon Mines (Produced 9.5 Million Lbs.)

Reclaimed Pigeon Mine (Produced 6 million lbs.)
Breccia Pipe Uranium Mining – A Typical Mine

**Kanab North Mine (on standby)**

- Produced 2.6 million lbs. $\text{U}_3\text{O}_8$ (approx. 200,000 lbs. remaining)
- Deformed bedding and faults define pipe
- Outcropping breccia extends to depth
- No ground water, no tailings ponds
- 1600 ft vertical shaft, central draw point
- Spiral incline and vent shaft
- Modified shrink stope underground mining
- 40 miners (2 shifts) mined 200-400 tons/day (10-20 trucks/day)
- No processing on site - all ore is trucked 250-300 miles to in Utah
Breccia Pipe Uranium Mining – Mine Life and Reclamation

Kanab North Mine

• Average mine life 2 to 4 years
• Average surface disturbance is only 20 acres
• Shafts backfilled with waste rock stockpiled at the surface
• Shaft sealed
• Headframe and buildings dismantled and moved to new site
• Stockpiled soil re-contoured and surface re-seeded
• Roads reclaimed
Historically defined reserves and resources of 27 million pounds $U_3O_8$ in 15 breccia pipes

(1.8 million lbs U3O8 per pipe)

- Reserves/production: $M \text{ lbs } U_3O_8 / \# \text{ pipes}$
- 7 Mineralized
- 6 Barren
- 6 under exploration
Arizona Strip Stratigraphy

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

Depth (ft)

- 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.
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 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.
Other pipes don’t reach the surface

- Blind pipes may potentially be larger deposits
- Hack 2 (7 million lbs U₃O₈) 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.

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.
Exploring for Blind Breccia Pipes

Airborne Geophysical Surveys

- Helicopter VTEM (vertical time-domain electromagnetic survey) for detection of breccia pipes
- Technology originally developed for deep copper/nickel exploration in Canada
- Never before tested on the AZ strip
- Much faster and deeper looking than old surface TDEM surveys
Arizona Strip Airborne VTEM Survey

Exploring for Blind Pipes

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 – The first anomaly to be tested by drilling

- Beautiful geophysical anomaly 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
Inversions and depth slices by Condor Consulting, Denver Colorado using the raw VTEM data.

Red is conductive.
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

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

Watch Depth Arrow

Pipe Center

Quaterra Resources Inc.
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
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

Depth (m)

Sulfide cap conductivity anomaly?
AIRBORNE VTEM SURVEY – Gump Model 319-371 m
AIRBORNE VTEM SURVEY – Gump Model 431-500 m

Gump BX Pipe Diagrammatic X-Section

Moenkopi
Kaibab
Toroweap
Coconino
Hermit
Esplanade

Depth (m)
AIRBORNE VTEM SURVEY – Gump Model 580-673 m
Breccia Pipe Density – Northern Arizona Strip District

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

How many mineralized pipes in the N district?

What is the potential of the northern district?

@ 2,600 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
USGS AZ Strip Uranium Endowment Estimate (Circular 1051)

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.

Arizona Strip Uranium District – Potential

**How many pipes? How much uranium?**

- Of the 1,296 mapped pipes in the Arizona Strip district.…

- 400 breccia pipes outcrop within the GC Park boundaries.

- More than 30 of these are mineralized and eroding into the Colorado River
Arizona Strip Uranium District – Distribution of Mineralization

*Not all of the district has mineralized pipes*

- Past exploration has shown that < 1/2 of the district has pipes with uranium mineralization
- The rest of the pipes are probably barren
- Current exploration is focusing on hidden or unmapped pipes
Arizona Strip – A Disappearing District

Most of the district has already been withdrawn from mining

- The area is host to numerous national parks, monuments, and recreation areas withdrawn from mining.
- Tribal Groups alarmed by activists will not allow uranium exploration.
- Only 1670 square miles of public (BLM & Forest) lands remained open to multiple use and within (or near) the area of known mineralization.
Arizona Strip Uranium District – What’s Left?

To protect the Grand Canyon?

- On January ‘09 Rep. Grijalva (D-Az) and Rahall (D-W.Va.) re-introduced the Grand Canyon Watersheds Protection Act to ban mining in 1,068,908 acres of the district.

- On July 20, 2009 Sec. of the Interior Salazar segregated the remaining district for two years pending a 20 year withdrawal from mineral entry.

- This action was taken even through no credible evidence exists of contamination in the Colorado resulting from mining activities.
Arizona Strip Uranium District – What may we loose?

Using USGS Circular 1051 estimates of 112.4 tons $eU_3O_8/mi^2$ the proposed withdrawal area of 1,670 has a uranium endowment 375 million lbs. (2)

<table>
<thead>
<tr>
<th>Region</th>
<th>Geologic Designation</th>
<th>Area (mi²)</th>
<th>Tons eU₃O₈</th>
<th>Tons/mi²</th>
<th>Million Lbs eU₃O₈</th>
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<td><strong>112.5</strong></td>
<td><strong>2,047</strong></td>
</tr>
</tbody>
</table>

Proposed withdrawal area: 1,670 acres, 1,068,908 acres

Arizona Strip Uranium District

What could the ultimate domestic energy impact of the district be?

• “The amount of energy in one pound of yellowcake is equivalent to 35.6 barrels of oil (208 x 10^6 Btus / 5.8 x 10^6 Btus in one barrel of crude oil).” (3)
• 375 million pounds of U3O8 has an energy equivalence 13.3 billion barrels of crude oil.
• This is equal to the total conventionally recoverable oil discovered in Prudhoe Bay; the largest oil field in North America.

(3) David Bradish, Manager - Energy Information, Nuclear Energy Institute, personal communication.
Arizona Strip Uranium District

What could be the economic impact of the district? (4)

Assumptions:
• Simultaneous operation of 6 producing mines
• 3 mines under development
• 3 mines in reclamation
• Production of 375 million lbs eU3O8 over a 42 year period

Conclusions:
• $29.4 billion in output impact over the 42-year life of the project
• $2 billion in federal and state corporate income taxes
• $168 million in state severance taxes
• $9.5 million in claims payments and fees to local governments
• 1,078 new jobs in the project area with a $40 million annual payroll

(4) American Clean Energy Resources Trust (ACERT) - Economic Impact of Uranium Mining on Coconino and Mohave Counties, Arizona – Prepared by Tetra Tech - September 2009
Arizona Strip Uranium District – Protect the Grand Canyon?

A Ten Year Proven Record of Clean and Responsible Mining

• 19 million lbs mined from 7 pipes with an exemplar legacy of reclamation and leaving no detectable surface or water contamination.

• Routine monitoring of the air, water and dust surrounding each of the mines during the 10 years of operations indicated no elevated levels of uranium as a result of the activities.

• All mining activity is separated by a 1,089-foot thick unsaturated, practically impermeable, layer of Supai Group Sandstone that protects the aquifer.

• Water studies of drainages in the National Park by the USGS failed to find a single water sample with uranium concentrations above the MCL for safe drinking water (5).

• A near-complete U of A study shows that the uranium in the Colorado river is naturally occurring.

• The area is one of the few public lands in the US where the multiple use status has been clearly established by Law. HR 3562 – the Arizona Strip Wilderness Act of 1983, passed by Congress in August 1984.

Arizona Strip Uranium District - Summary & Conclusions

- The Arizona Strip remains a young district – many tons of uranium remain to be discovered by existing technology.
- High Grades, no ground water, and excellent rock conditions may also rank the Arizona breccia pipes among some of the world’s most economical ore deposits.
- 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.
- It has a ten year proven record of clean and responsible mining.
- It has an exemplar legacy of reclamation.
- It has tremendous mineral potential – 375 million lbs U₃O₈ (energy equivalent to >13 billion barrels of oil).
- It has the potential for 1000s of new jobs and millions of dollars in state and federal revenues.

These resources are vital to the future economies of southern Utah and northern Arizona and the energy security of the United States.
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Management and Shareholders of Quaterra Resources

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