The Mississippian-Age Oil Sands of Alabama: A Resource Worth (Re)Evaluation*

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Search and Discovery Article #80491 (2015)
Posted November 9, 2015

*Adapted from oral presentation given at AAPG Annual Convention & Exhibition, Denver, Colorado, May 31-June 3, 2015

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Abstract

The hydrocarbon potential of the Mississippian-age Hartselle Sandstone in northwestern Alabama and northeastern Mississippi has long been known. The most recent publically available systematic study on the resource, Gary Wilson's Geological Survey of Alabama (GSA) Bulletin 111 (B111), was completed almost three decades ago. Wilson estimated that Alabama's surface and subsurface oil sands deposits contain up to 7.5 billion barrels of hydrocarbon, with up to 350 million barrels within 50 feet of the surface. No commercial exploitation of these resources for the purpose of extracting oil has occurred to date, owing to various economic and limiting technological factors; however, interest has recently increased, particularly in light of growing desire for North American energy independence. Alabama Governor Dr. Robert Bentley established the Alabama Oil Sands Program (AOSP) at the GSA and the State Oil and Gas Board (OGB) of Alabama in early 2014. The purpose of the AOSP is to provide a road map for an initiative that facilitates commercial development of Alabama's oil sands resources; assist in the realization of potential economic and societal benefits that accrue from prudent, orderly, and environmentally sound development of Alabama's oil sands; provide focus for oil sands activities and initiatives in the state conducting complete geological, geochemical, geophysical, and engineering analyses; and evaluate and develop appropriate legal and regulatory frameworks. Work within the AOSP has included a comprehensive review of existing data at the GSA and OGB, including data from wells, cores, and field notes. Fieldwork has commenced, building on B111. Specific plans include additional cores and analyses of the rock and bitumen, with particular attention to data that would inform decisions about feasible economic development. Reservoir models and reserve estimates will then be recalculated using up-to-date methodologies. Information is being sought about newer surface and *in situ* extraction technologies that could be economically employed on small- to medium-sized deposits such as this. These facts will allow for a comprehensive assessment of the potential development of Alabama's Mississippian-age Hartselle oil sands.

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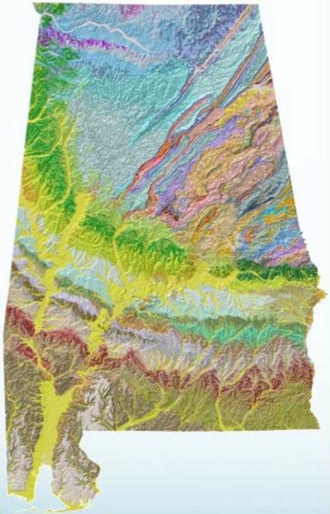
Geological Survey of Alabama

Barriers and Drivers of Resource Development

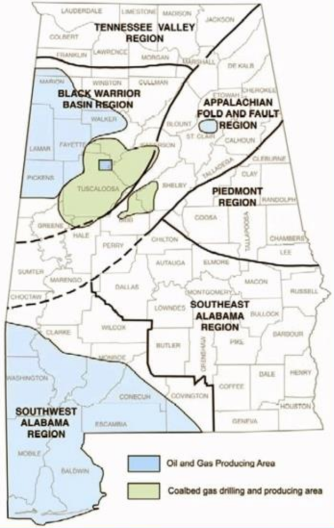
- Environmental factors
- Regulatory factors
- Public Policy
- Economic factors
- Technologic factors

Presenter's notes: These factors affect whether a resource can be developed. Note that these factors can change through time – what was once not economic can become economic with new technologies or with resource price, for example. Regulations or public policy can be prohibitive to development, but economic factors can affect these as well, etc.

Alabama's Fossil Fuel Energy Endowment



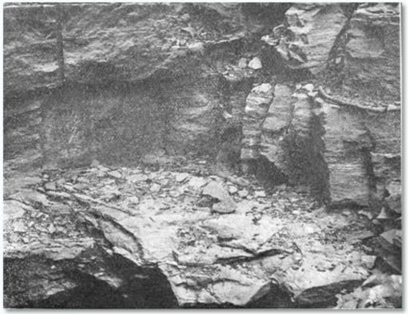
Geology of Alabama

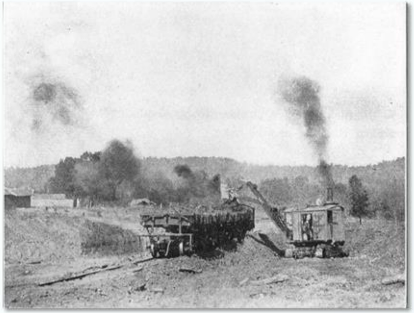


Significant Activity Areas

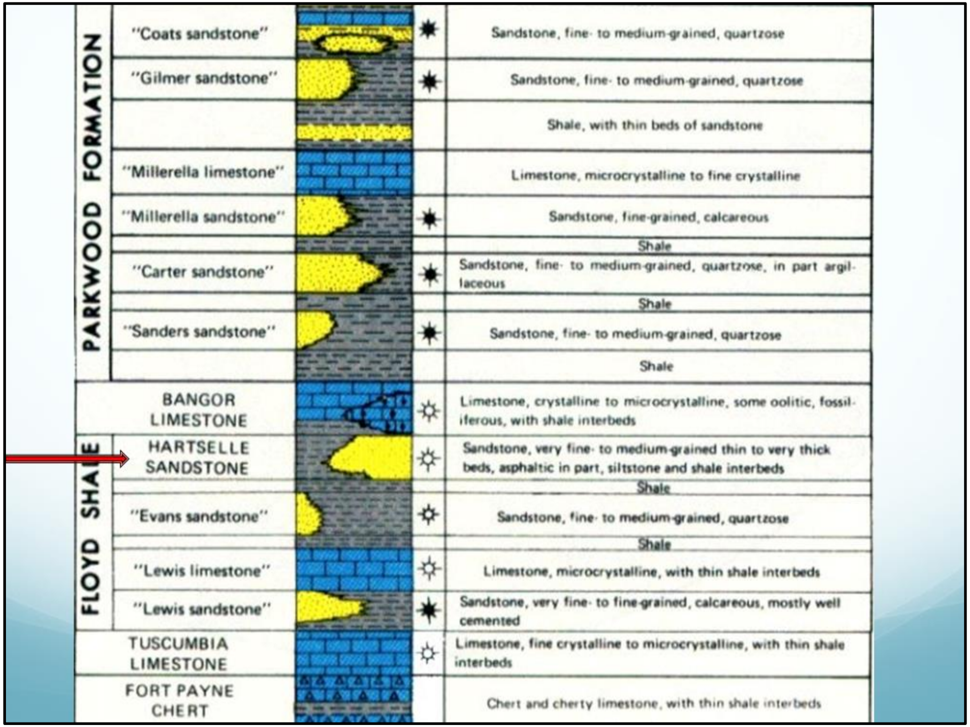
Presenter's notes: Coal - Black Warrior Basin Coal Measures, Coastal Plain Lignite
Conventional Oil and Natural Gas - SW Alabama, BWB
Unconventional Gas – CBM BWB, Gas shale of N AL
Unconventional Oil – Oil Shale, Oil Sands of N AL

Oil Sands in Alabama



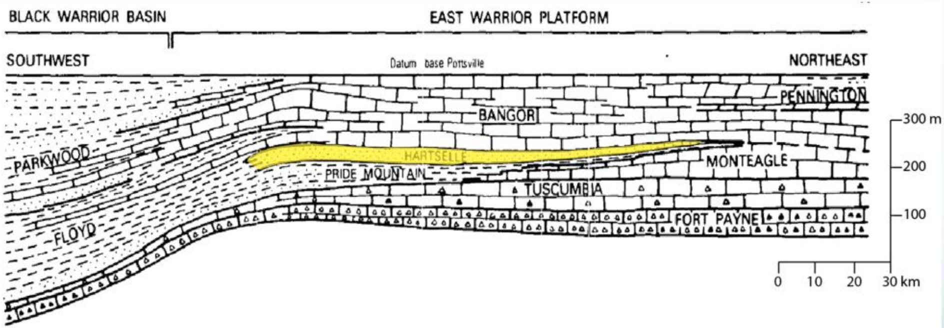


Presenter's notes: Historically the asphaltic potential of the Mississippian-age Hartselle Sandstone in northwestern Alabama and northeastern Mississippi has long been known.
In the late 1800s the presence of bituminous sandstones were recorded at scattered locations in Colbert, Lawrence, and Morgan Counties.
In those early years, semi-liquid asphaltum was extracted by crude heating methods. However, this was not found profitable and never went beyond experimental.
Pictured here are photos published in Geological Survey of Alabama Special Report 13 in 1925, taken in Cherokee, Alabama at Cherokee Rock Asphalt Company – (TL) Quarry face showing stratification of asphaltic sandstone– (TR) Active Cherokee Quarry stripping operation in progress - (LL) diamond drill testing - (LR) Plant of Cherokee Rock Asphalt Company



Presenter's notes: This is the generalized stratigraphy of Northwestern Alabama:
Bitumen deposits in northwestern Alabama occur primarily within rocks of Late Mississippian age.
Most significant asphalt and bitumen deposits occur within the Hartselle Sandstone.
The Hartselle Sandstone is a fine-grained quartzose sandstone that is generally light colored except where impregnated with asphalt.

Depositional Structure
Hartselle Sandstone



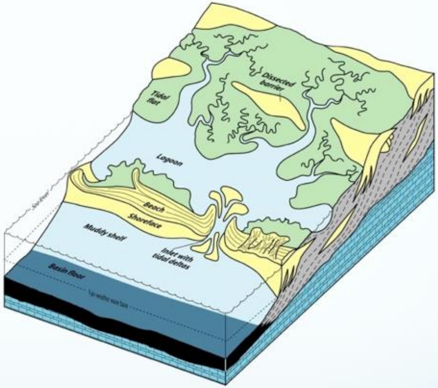
(Thomas, 1982)

Presenter's notes: This is a cross section of Mississippian age rocks in Alabama displaying the depositional structure of the Hartselle Sandstone.
Cross section taken from the Black Warrior Basin (western Alabama) to the northeastern corner of Alabama.
In this we can see the Hartselle Sandstone bounded by the Bangor LS and the Tuscumbia LS. The Hartselle SS and the Floyd Shale comprise a sequence of predominantly clastic sediments that were transported by marine processes and deposited along the margin of a broad stable shelf known as the "East Warrior platform". (Thomas, 1982)
The Hartselle Sandstone is richly impregnated with bitumen. It has a clean, porous and permeable characteristic. This in turn supports a conclusion that the bitumen was not deposited in place, but instead formed elsewhere and migrated to its present position along preferentially chosen pathways of least resistance. (Wilson, 1987)
The bitumens most often are found in accumulations within the uppermost parts of porous sandstones, and this characteristic would also tend to support a theory of migration.

Geological Society of America Bulletin
Paleogeographic relationship of a Mississippian barrier-island and shelf-bar system (Hartselle Sandstone) in Alabama to the Appalachian-Ouachita erogenic belt
William A. Thomas and Greg H. Mack, 1982
Sequential Filling of A Late Paleozoic Foreland Basin
(Mars and Thomas 1999)

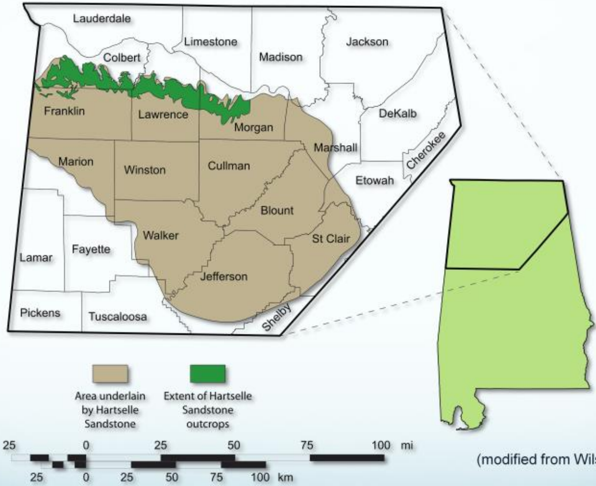
Hartselle Sandstone Characterization

- Porosities: <5% to 24%
- Permeability:<10 mD to 100+ mD
- Oil saturations: trace to >700 barrels per acre-foot
- >12,000 barrels of bitumen per acre



Presenter's notes: Character of the bitumens in Hartselle is "primarily that of a typical asphalt containing hydrocarbons that have been variably biodegradated." The depositional model (i.e., how the Hartselle originated) is that of a beach-barrier system as shown above.
Porosities: <5% to 24%
Permeability: <10 mD to 100+ mD
Oil saturations: trace to >700 barrels per acre-foot
>12,000 barrels of bitumen per acre
Wilson estimated that Alabama's surface and subsurface oil sands deposits contain up to *7.5 billion* barrels of hydrocarbon, with *up to 350 million barrels within 50 feet* of the surface – and the vast majority of this is contained within the Hartselle.
Left: Example of the Hartselle SS which is a quartzose sandstone that is light-colored, fine-grained, well sorted, generally thick bedded to massive. This sample has bitumen staining
Right: Hartselle SS saturated with bitumen

GSA Bulletin 111 (Wilson, 1987)

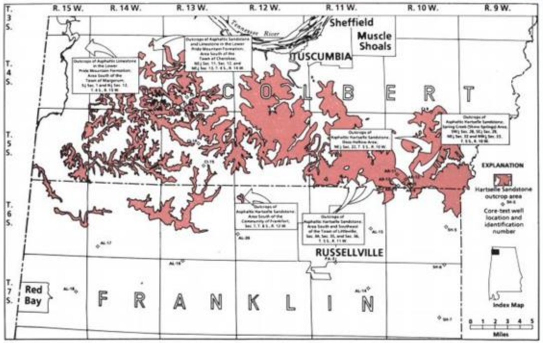


(modified from Wilson, 1987)

7.5 billion barrels speculated in subsurface (~350 million barrels at <50 feet depth)

Presenter's notes: Alabama's Oil Sands deposits are primarily located within the Mississippian age Hartselle Sandstone.
This is a modern representation of the estimated extent of Hartselle Sandstone in AL – note that the extent in Mississippi is not as well known. (modified from Wilson, 1987).
Hartselle Sandstone outcrops along a 70 mile (112 km) belt in northeast Alabama that extends into Mississippi.
No modern commercial exploitation of these resources for the purpose of extracting oil has occurred to date, owing to various economic and technical factors.
Modified from: GSA Bulletin 111, Wilson 1987

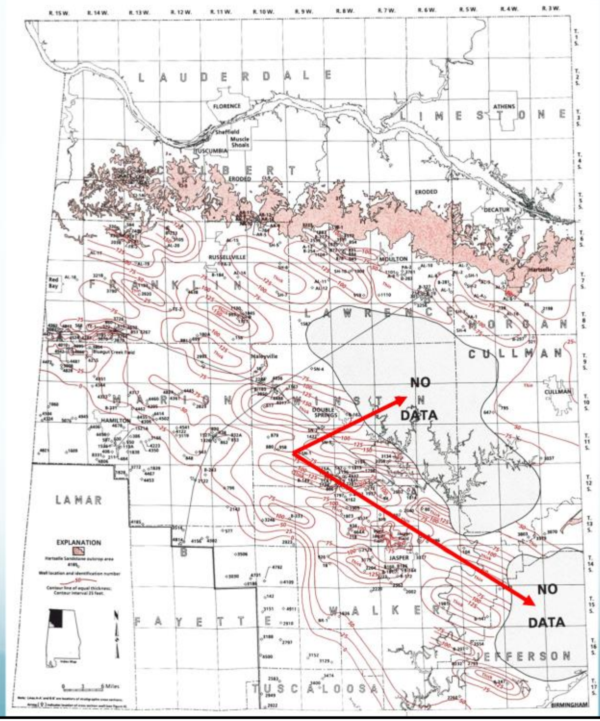
Outcrops of the Hartselle SS



(from Wilson, 1987)

Presenter's notes: Great detail was focused on outcrops of asphaltic rock that is found within the 70 mile-long belt that extends from near the city of Hartselle in Morgan County, westward into Colbert County near the Alabama-Mississippi state line.

Geological Survey of Alabama Bulletin 111 by Gary Wilson, 1987



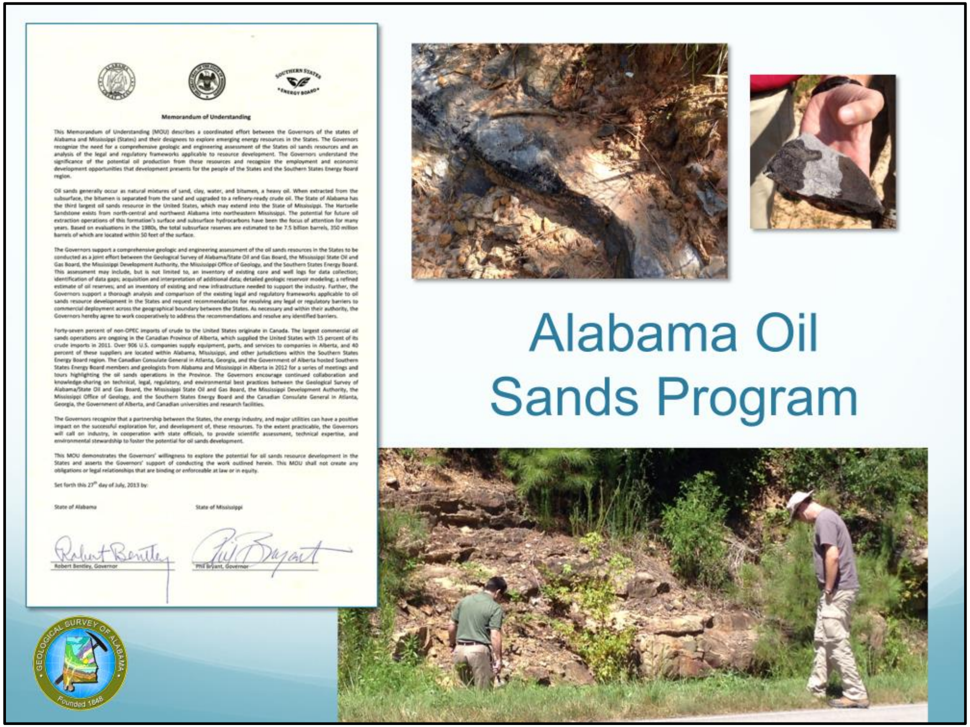
(from Wilson, 1987)

Presenter's notes: One of the main products of Bulletin 111 was an isopach map for the Hartselle Sandstone.

This study was an overview of the area.

Because of this large study area there are gaps in the data.

We would like to go back and build on this work and fill in with more detailed information to generate a more complete picture of the hydrocarbons in the Hartselle Sandstone.



Presenter's notes: Recently, there has been renewed interest in expanding resource development within the U.S.

July 2013 – Memorandum of Understanding (MOU) describing a coordinated effort between the Governors of the states of Alabama and Mississippi and their designees to explore emerging energy resources in the States.

MOU is to support a comprehensive geologic and engineering assessment of the oil sands resources in the Alabama and Mississippi.

There has not been a publically available, systematic scientific assessment of Alabama's oil sands since Bulletin 111, Wilson's 1987 report.

Early in 2014, Governor Bentley of Alabama established the Alabama Oil Sands Program (AOSP) at the GSA/OGB.

The Purpose of the Alabama Oil Sands Program:

To provide a road map for an initiative that facilitates commercial development of Alabama's oil sands resources,

To assist in the realization of potential economic and societal benefits that accrue from prudent, orderly, and environmentally sound development of Alabama's oil sands,

To provide a focus for oil sands activities and initiatives in the state, conducting complete geological, geochemical, geophysical, and engineering analyses,

To evaluate and develop appropriate legal and regulatory frameworks.

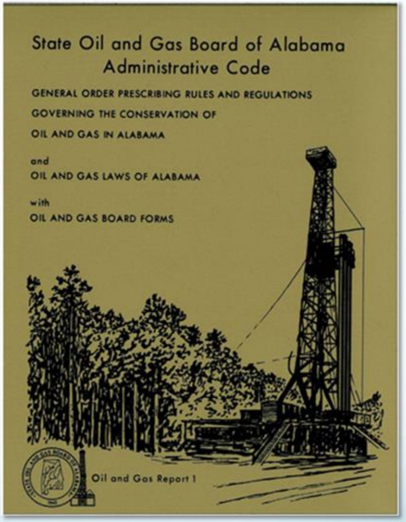
Alabama Oil Sands Program Purpose

- Provide a road map for assessment and development
- Assist in the realization of potential economic and societal benefits
- Provide a focus for oil sands activities and initiatives in the state
- Evaluate and develop appropriate legal and regulatory frameworks

Presenter's notes: To provide a road map for an initiative that facilitates commercial development of Alabama's oil sands resources.
To assist in the realization of potential economic and societal benefits that accrue from prudent, orderly, and environmentally sound development of Alabama's oil sands.
To provide a focus for oil sands activities and initiatives in the state, conducting complete geological, geochemical, geophysical, and engineering analyses.
To evaluate and develop appropriate legal and regulatory frameworks.

Regulatory Framework

Process allows the public an ample opportunity to comment and be heard



Interagency interaction and coordination key

Presenter's notes: HB 503, signed into law May 2013, specifies the authority of the Oil and Gas Board relating to oil sands development; provides for fees to fracture a coal group or geologic formation; and authorizes the Board by rule to set fees for operations to recover oil from oil sands.

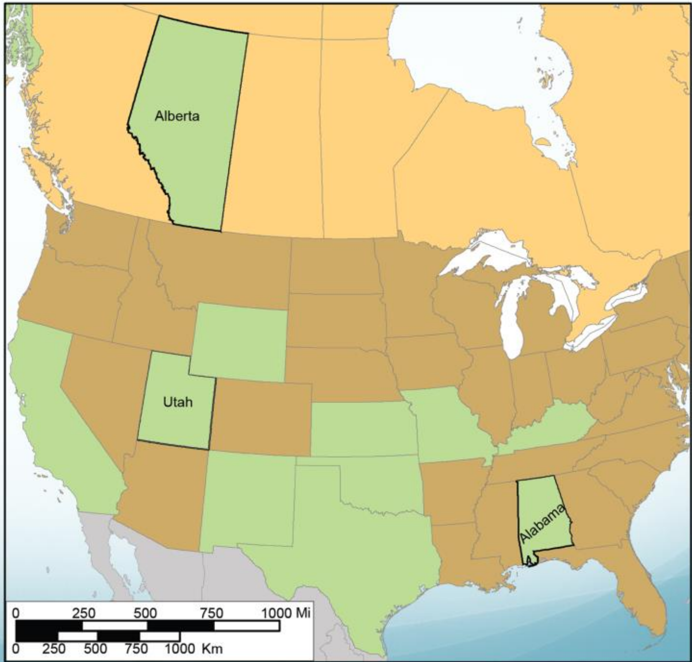
- Oil and gas statutes with legislative amendments as needed and necessary
- Regulations, with Administrative amendments and waivers as appropriate
- Special Field Rules for each new field established

Interagency coordination – interaction with, and assistance from, Southern States Energy Board, national associations of states (IOGCC, Groundwater Protection Council), other state agencies (both in and out of Alabama), and international organizations with experience

1. Publication of proposed rule
2. Notice placed on OGB's docket
3. Rule officially proposed; published in the Alabama Administrative Monthly, initiating minimum of 35-day comment period
4. After OGB approves rule, sent to legislative committee to review

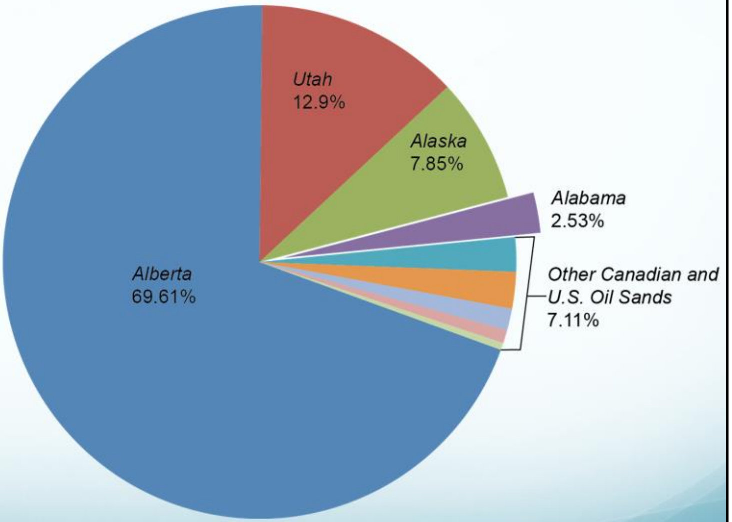
Picture from http://www.oilsands.alberta.ca/2831.html – Oil Sands > About the Oil Sands > Integrated Resource Management. Land Use Planning

U.S and Canadian Oil Sands



Presenter's notes: 11 states are Alabama, Alaska, California, Kansas, Kentucky, Missouri, New Mexico, Oklahoma, Texas, Utah, and Wyoming.
Alabama's resource may extend into Mississippi.
Utah has largest oil sands resource in U.S., followed by Alaska, then Alabama. Texas has similar resources to Alabama.
In the United States there are 11 states with significant oil sands deposits.
Those 11 states are Alabama, Alaska, California, Kansas, Kentucky, Missouri, New Mexico, Oklahoma, Texas, Utah, and Wyoming.

U.S and Canadian Oil Sands



Presenter's notes: Percentages from Hein (2006). Heavy Oil and Oil (Tar) Sands in North America: An Overview & Summary of Contributions: Natural Resources Research, v. 15, no. 2, p. 67-84, doi:10.1007/s11053-006-9016-3.

bbls (from Hein 2006):

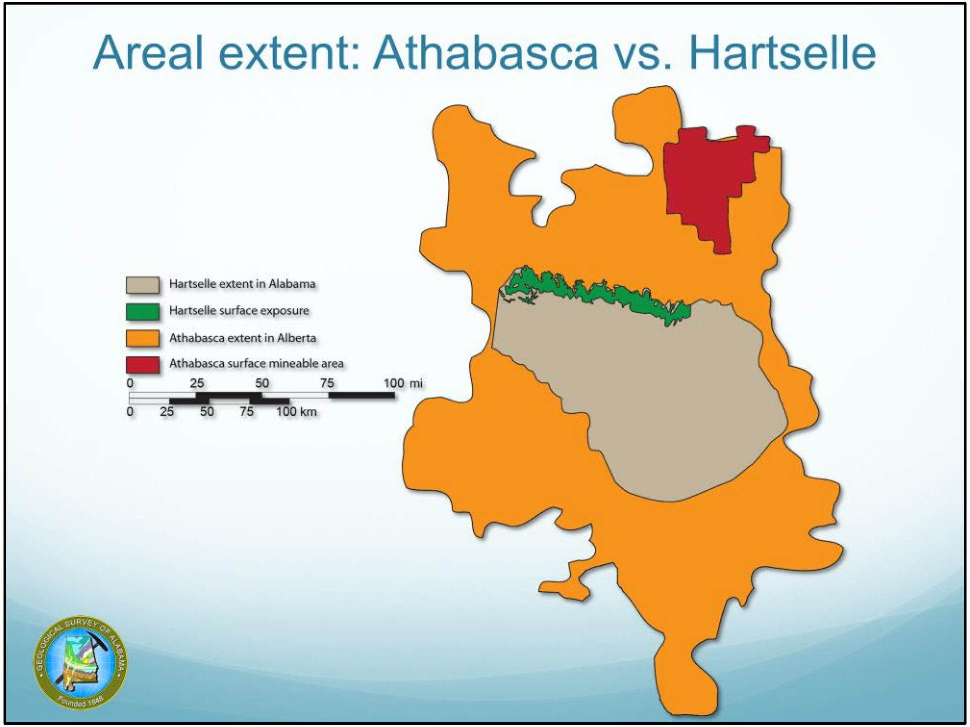
Alberta – 174.5

Utah – 32.33 (Schamel 2015 (abstract for AAPG) states an estimate of 16 bbls)

Alaska – 19.00

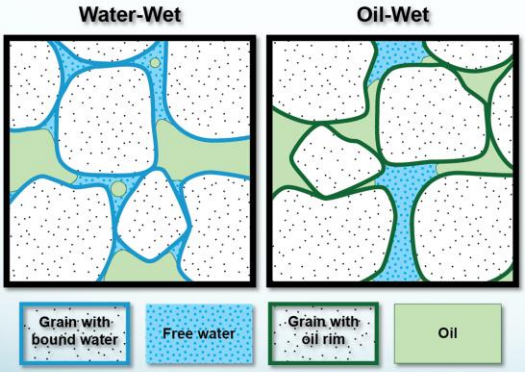
Alabama – 6.36 (Wilson 1987 estimates 7.5 bbls)

Texas – 5.44



Presenter’s notes: Athabasca – orange subsurface, red surface
Hartselle – tan subsurface, green surface
Another difference between Canadian and Alabama oil sands is the volume of the resource. The Athabasca Oil Sands alone are estimated to have 1.7 TRILLION Bbls vs 7.5 billion in the Hartselle
This image shows the extent of Athabasca sands, vs area of the Hartselle. The surface mineable area of the Hartselle is less that ¼ of the total Hartselle.

Athabasca and Hartselle: Differences



	Hartselle (Alabama)	Athabasca (Alberta)
C %	81.4	83.1
H %	10.2	10.6
C/H ratio	8.0	7.8
Ni %	0.8	0.4
S %	1.7	4.8
O %	2.5	2.1

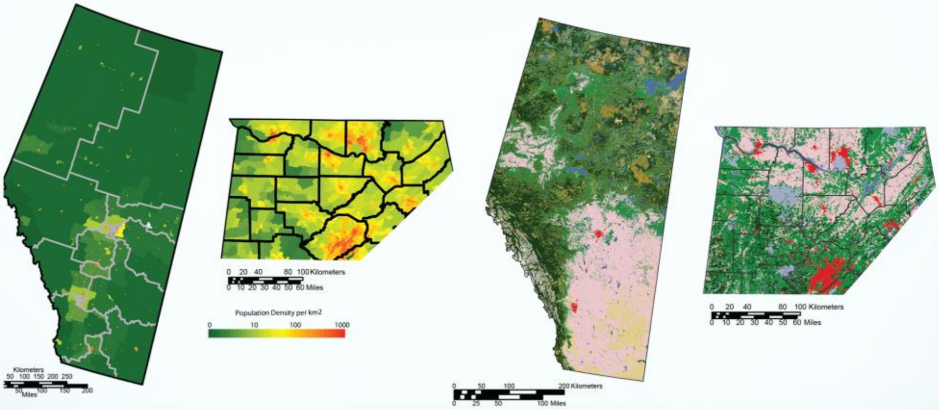
Presenter's notes: Right Image: Left – Water Wet. Right – Oil Wet

One key difference between the Canadian oil sands and Alabama oil sands are in how the water and oil interact with the sand. Canada's oil sands are hydrophilic or water wet. Each grain of sand is covered by a film of water, which is then surrounded by a slick of heavy oil (bitumen). In contrast, the oil sands in Alabama (and the rest of the U.S.) are oil wet rather than water wet. This means the bitumen adheres directly to the sand grains.

Oil wet sands do not respond as well to water/steam processes as water wet sands do. Therefore different technologies must be used for the oil wet sands of Alabama. Discussions in Alabama have centered on newer technologies that employ closed-loop, solvent-based systems, which address many environmental issues and are more amenable to application in small- to medium-sized deposits. Pilot studies suggest a significant reduction in water use, energy consumed, and non-reusable tailings by the solvent-based systems.

Compositional differences:

Averaged ultimate analyses of bitumen from the Hartselle Sandstone (Alabama, from Wilson, 1987), Asphalt Ridge (Utah, from Wood and Ritzma, 1972), Athabasca (Alberta, from Starr et al., 1981), and Peace River (Alberta, from Starr et al., 1981).



Population Density and Land Use Differences

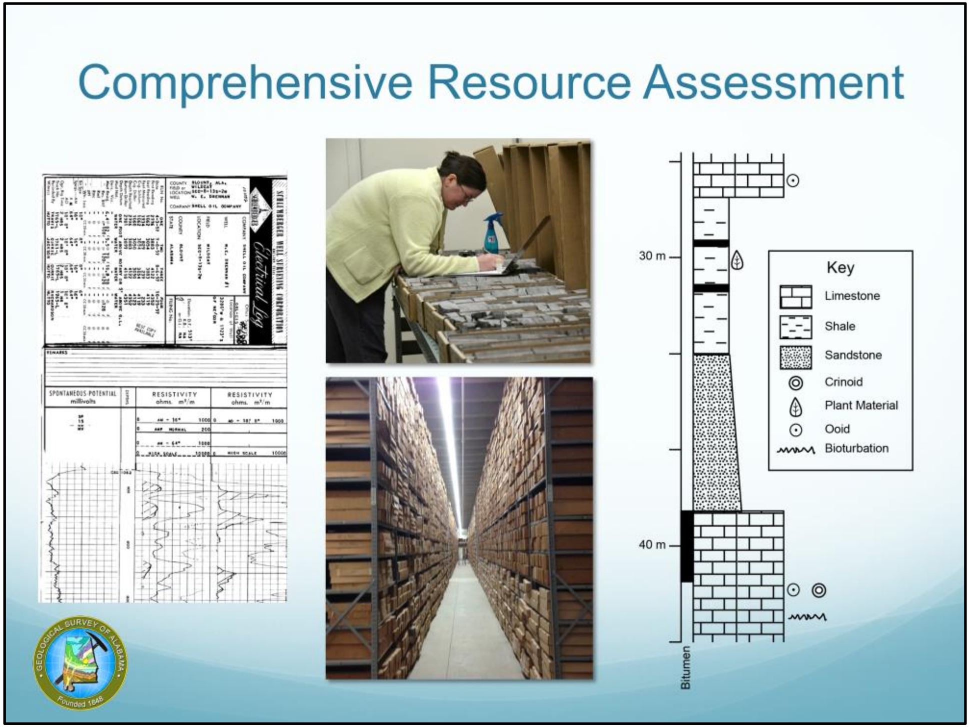
Presenter's notes: Other differences – population density.

Most of the area underlain by the Athabasca has a population of less than 2 people per km^2, while the areas underlain by the Hartselle where surface extraction is possible the population density ranges from 2 to more than 1,000 people per km^2 (Figure 6). Particularly when focusing on regions with potential surface development, it is apparent that Alabama will have more challenges with existing population if surface extraction were to be pursued (U.S. Census Bureau, 2011; Statistics Canada, 2012).

Other differences – land use/cover.

Land cover and usage across the area underlain by the Hartselle Sandstone varies considerably, but is predominantly cropland (Figure 7), while areas underlain by the Athabasca are predominantly forested, grassland, and shrubland (USGS, 2012; CEC, 2013). Thus, land cover will provide more challenges to surface extraction in Alabama than in Alberta.

In addition to differences in the population land cover/use, there are differences in who owns the resource. Mineral rights in Canada are simple and straightforward - the Crown owns them. In the U.S., mineral rights are more complicated. Mineral rights are generally held in private ownership, with the exception of publicly owned lands, and may be owned separately from the surface rights. The private ownership and separation of surface and mineral rights, and the relatively large numbers of those owners, makes consolidating enough land (buying or leasing) to make surface extraction economically viable may be difficult at best and nearly impossible in many areas held in private ownership.



Presenter's notes: We have completed Phase I:

Which was an Audit of Current Data and Resources (Achieves Goal of MOU).
Conducted a Literature Review– 19 AL Specific, 1 MS Specific, 38 Heavy Oil.
Conducted a Physical Samples Review -25 Possible Cores, All Permitted Hartselle Wells.
We are also reviewing the Records and Methodology and validity of method(s) used in previous studies.

Comprehensive Resource Assessment

Presenter's notes: We are also reviewing the Records and Methodology and validity of method(s) used in previous studies.

In Phase II: Proposed a Strategy for Filling the Gaps of previous studies.

Our Scope of Work will include:

Exploratory coring program and the use of Ground Penetrating Radar.

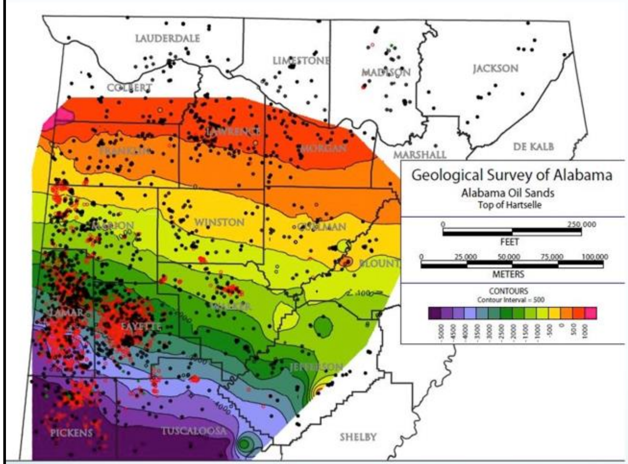
Sample prep and testing, including thin sections.

Determine distribution of porosity, permeability, fluid composition in the Hartselle.

Understand rock mechanics. Grindability will be an important determinant of economics for near-surface development.

Mechanical properties also will help identify viable techniques for drilling and well completion for deeper subsurface operations.

Develop a predictive model that can guide exploration and development.

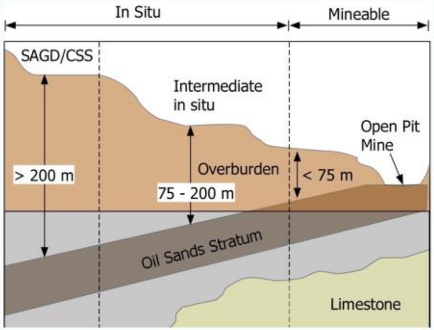


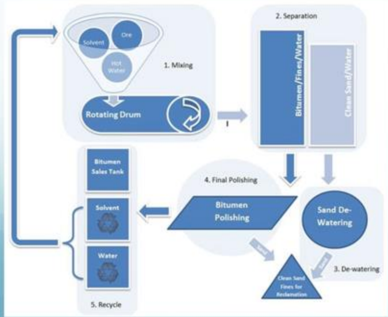
- Reserve estimates
- Reservoir models
- Other information critical to prudent development

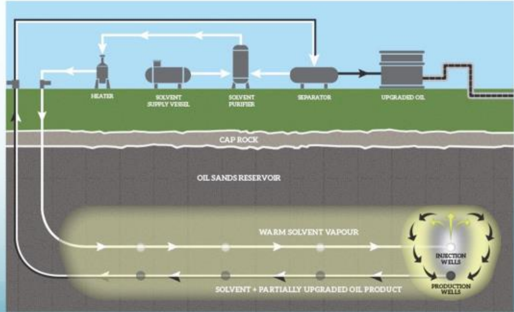
Program Deliverables

Presenter's notes: Alabama Oils Sands Program:
Hope to provide:
Updated Reserve estimates, reservoir models, and an evaluation of extraction technologies.
Other information critical to prudent development.
Much of the previous work on oil sands was conducted in Canada. Thus, to guide our research, we need to look at the similarities, and possibly more importantly, the differences, between Canadian and Alabamian oil sands.

Development Methods & Extraction Technology







Presenter's notes: Because of the scale of the resource, the hydrophilic/hydrophobic difference, and the difference in consolidation of the material particularly at the surface (pictures, left - example of Canadian Oil sands. Not as tightly consolidated at the surface as the Hartselle, Right - hand sample from Hartselle Sandstone, collected from Hartselle, AL. Very tightly consolidated.), development methods will need to be different. However, they can still be classified in two main ways – surface mineable vs in-situ development (upper left drawing). Surface mining is only viable under certain conditions – e.g., near surface, high concentrations. In-situ has broader applicability.

Currently, oil sands development in Alberta are 52% surface mining, 48% in-situ. In Alabama much more of the resource is amenable to *in situ* development than surface mining.

Current focus is for bitumen extraction from surface operations centering on newer technologies that employ closed-loop, solvent-based systems, which address many environmental issues and are more amenable to application in small- to medium-sized deposits. Techniques explored for *in situ* recovery of deeper deposits include traditional methods employing steam, as well as other techniques using solvents to mobilize the bitumen.

Bottom left Image from http://www.usoilsandsinc.com/index.php?page=extraction_process This is the extraction technology that is proposed for the Utah oil sands.

Deeper deposits would utilize *in situ* recovery techniques, most likely using solvents. Bottom right image from n-solv.

Public Engagement

(Photos From TimesDaily.com)

Presenter's notes: Keeping the public informed and involved is a major program goal.
These are photos taken from a Community informational meeting in June, 2014 in Tuscumbia, AL.
The public is invited to learn about what's happening with development, what could happen, and for several governmental agencies to listen to community perception and concerns.
One reason that community engagement is critical is to help provide information as to the DIFFERENCES between what we hear about (e.g., Athabasca) and what is present in Alabama (and the rest of the continental US), and to provide information about the different pathways to development.

Photo from TimesDaily.com (online version of a Florence, AL, newspaper)

Barriers and Drivers of Resource Development: Alabama Oil Sands

- Public Policy
  - Establishment of the Alabama Oil Sands program demonstrates public policy supporting research and possible development of the resource.
- Environmental factors
  - Huge concern with the public, so proactive community engagement, as well as robust regulatory development and mindful technologic development critical.
- Regulatory factors
  - Alabama has long history of hydrocarbon development regulation that supports both the needs of industry and of the public.

Barriers and Drivers of Resource Development: Alabama Oil Sands

- Economic factors
  - With current technologies, extensive development not likely at current prices.
- Technologic factors
  - Under development, new technologies might prove to change the economic outlook. Better understanding of the character of the resource will help define what technologies to pursue for prudent and economic development

Presenter’s notes: These factors affect whether a resource can be developed. Note that these factors can change through time – what was once not economic can become economic with new technologies or with resource price, for example. Regulations or public policy can be prohibitive to development, but economic factors can affect these as well, etc.