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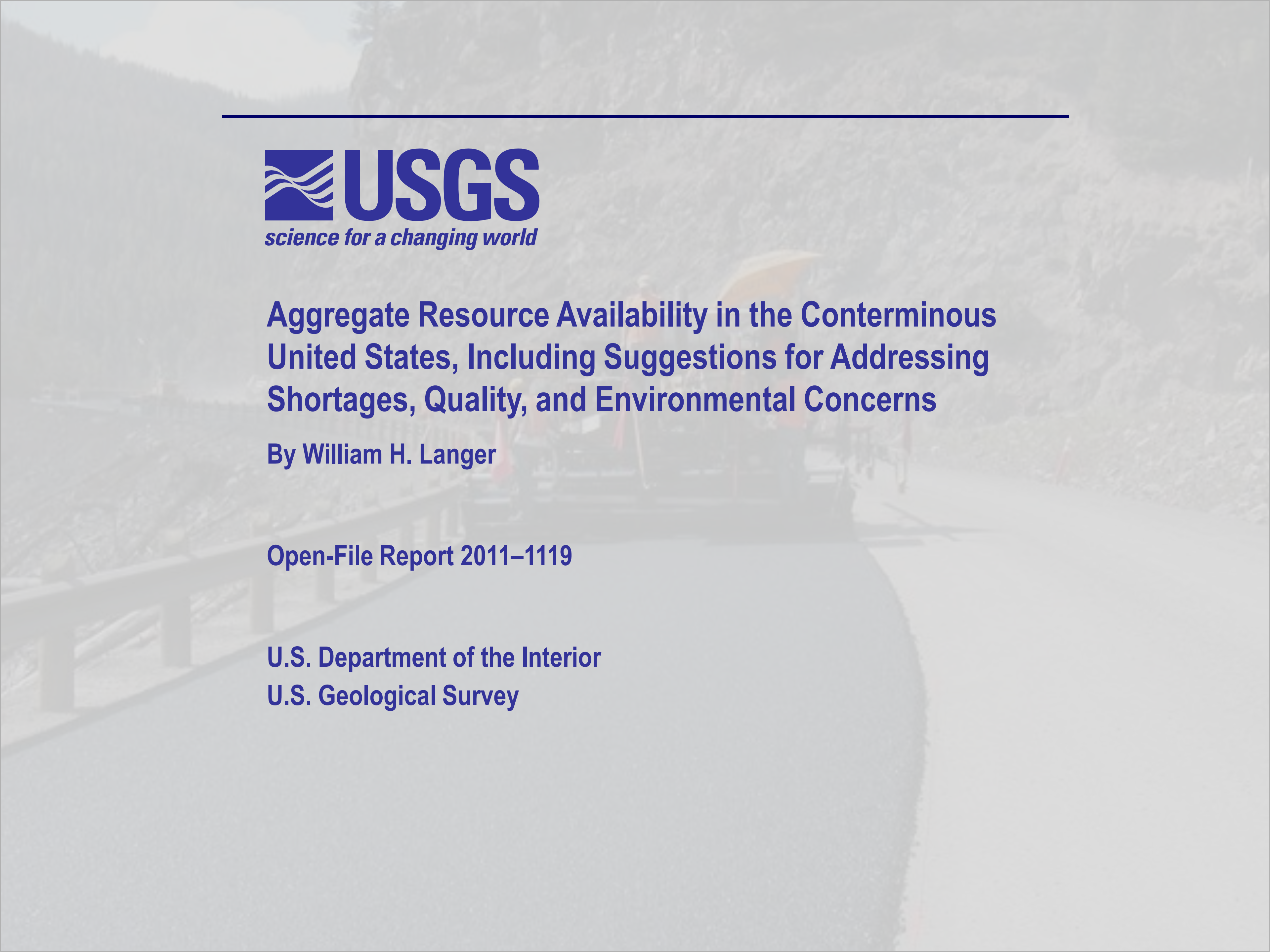
Aggregate Resource Availability in the Conterminous United States,

Including Suggestions for Addressing Shortages, Quality, and Environmental Concerns

Open-File Report 2011–1119

U.S. Department of the Interior
U.S. Geological Survey



Aggregate Resource Availability in the Conterminous United States, Including Suggestions for Addressing Shortages, Quality, and Environmental Concerns

By William H. Langer

Open-File Report 2011–1119

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

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Purpose and scope

Background photograph from the Federal Highway Administration

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Abstract

Purpose and scope

Background photograph from the Federal Highway Administration

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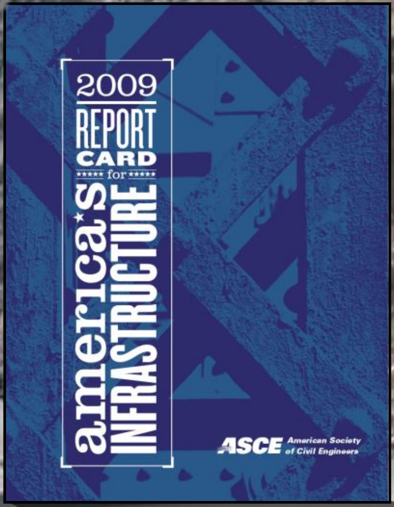
Introduction



One third of our major roads are in poor or mediocre condition.

One fourth of our bridges are structurally deficient or functionally obsolete.

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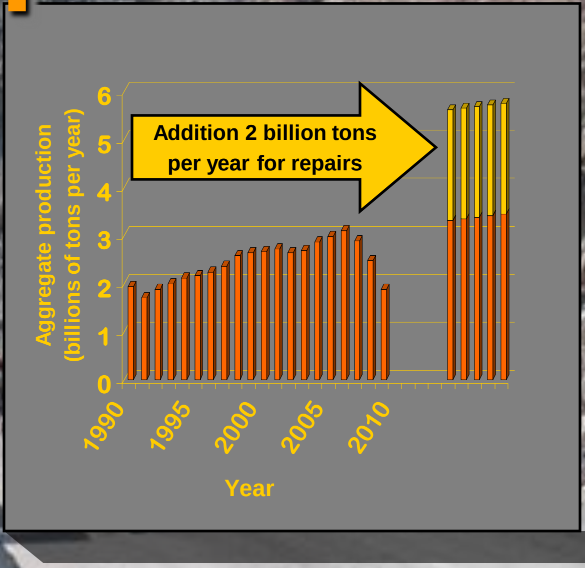
Introduction



One third of our major roads are in poor or mediocre condition.

One fourth of our bridges are structurally deficient or functionally obsolete.

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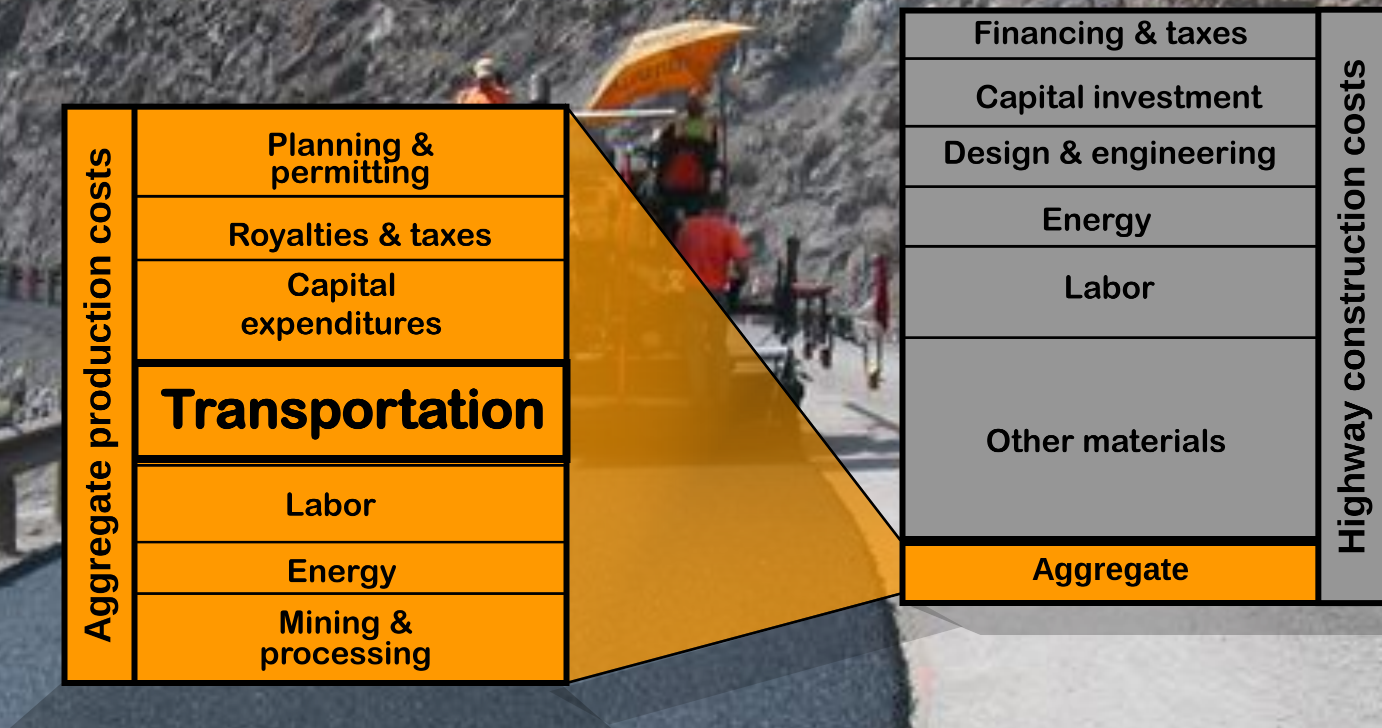
Introduction

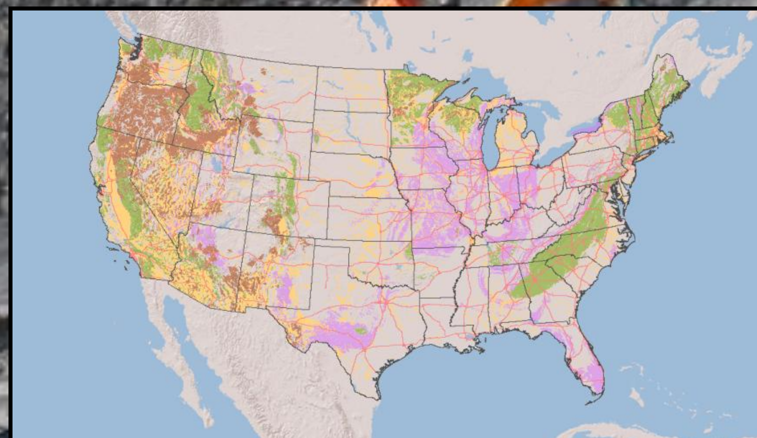
Aggregate is about 5-10 percent of highway construction.

Introduction



Transportation of 30 to 50 miles can more than double the put-in-place cost of aggregate.

Presentation Outline

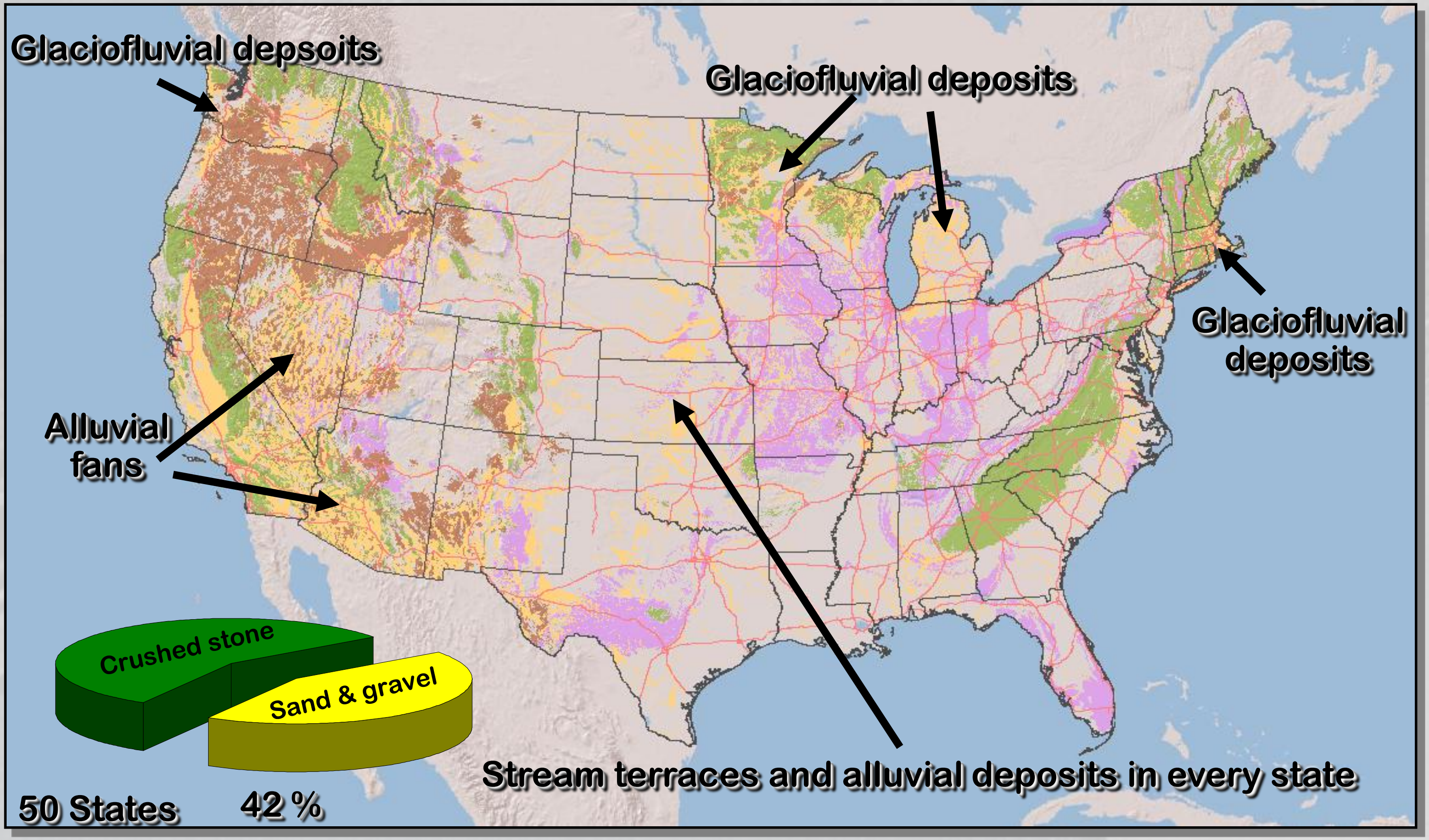


Aggregate supply

Quality, societal and *environmental* issues *limiting access* to aggregate

Case studies

Where aggregate occurs
Sand & gravel



Glaciofluvial, alluvial fans, stream terraces, and alluvium.

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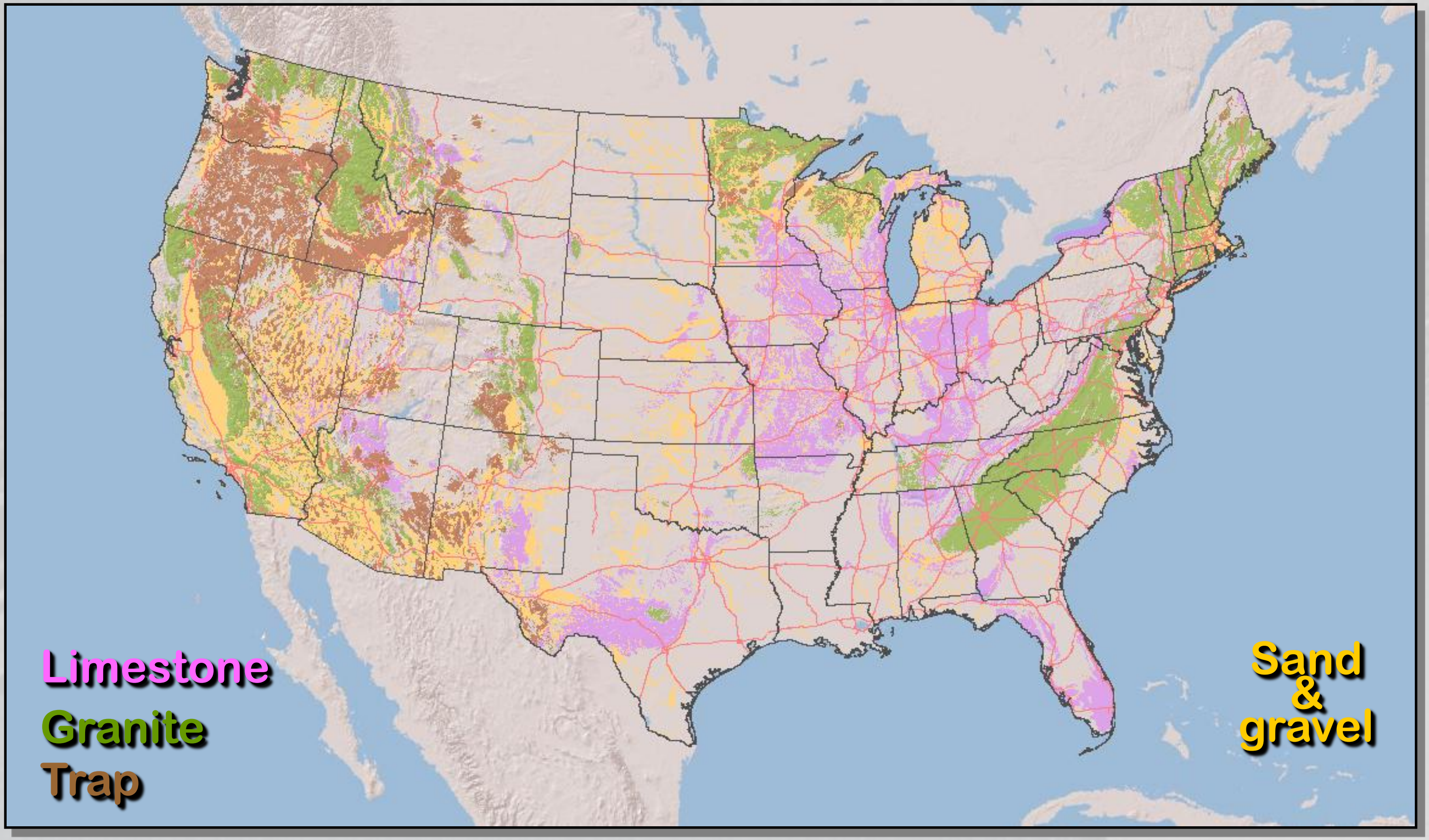
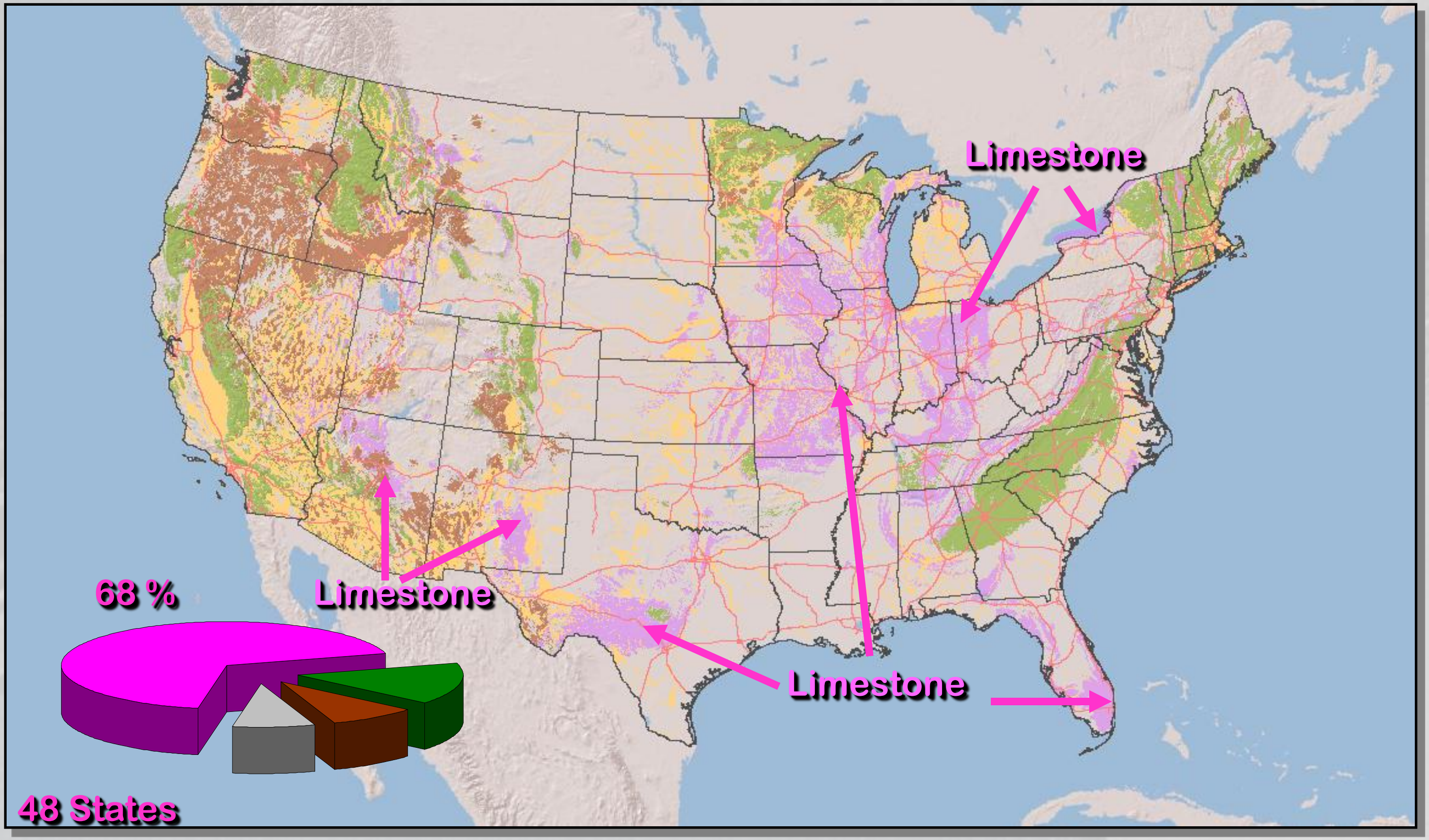
Where aggregate occurs

Crushed stone



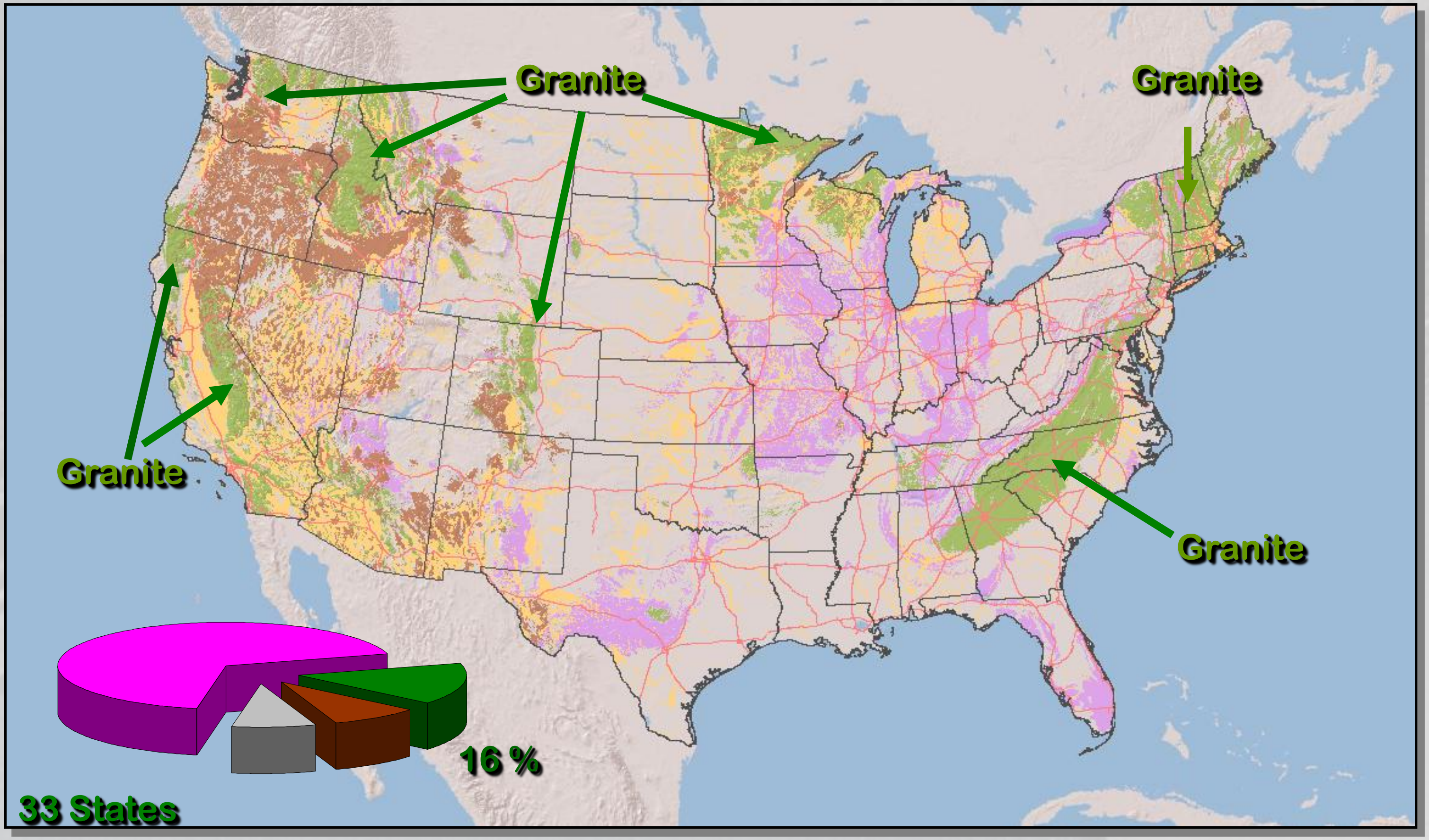
American Society for Testing and Materials (2011)
Designation C 294
Generally not applied

Limestone



- Any common carbonate rock - limestone, dolomite, marble

Granite



- Igneous or metamorphic (crystalline) rocks
- Medium or coarse grained, any color – granite, gabbro, gneiss

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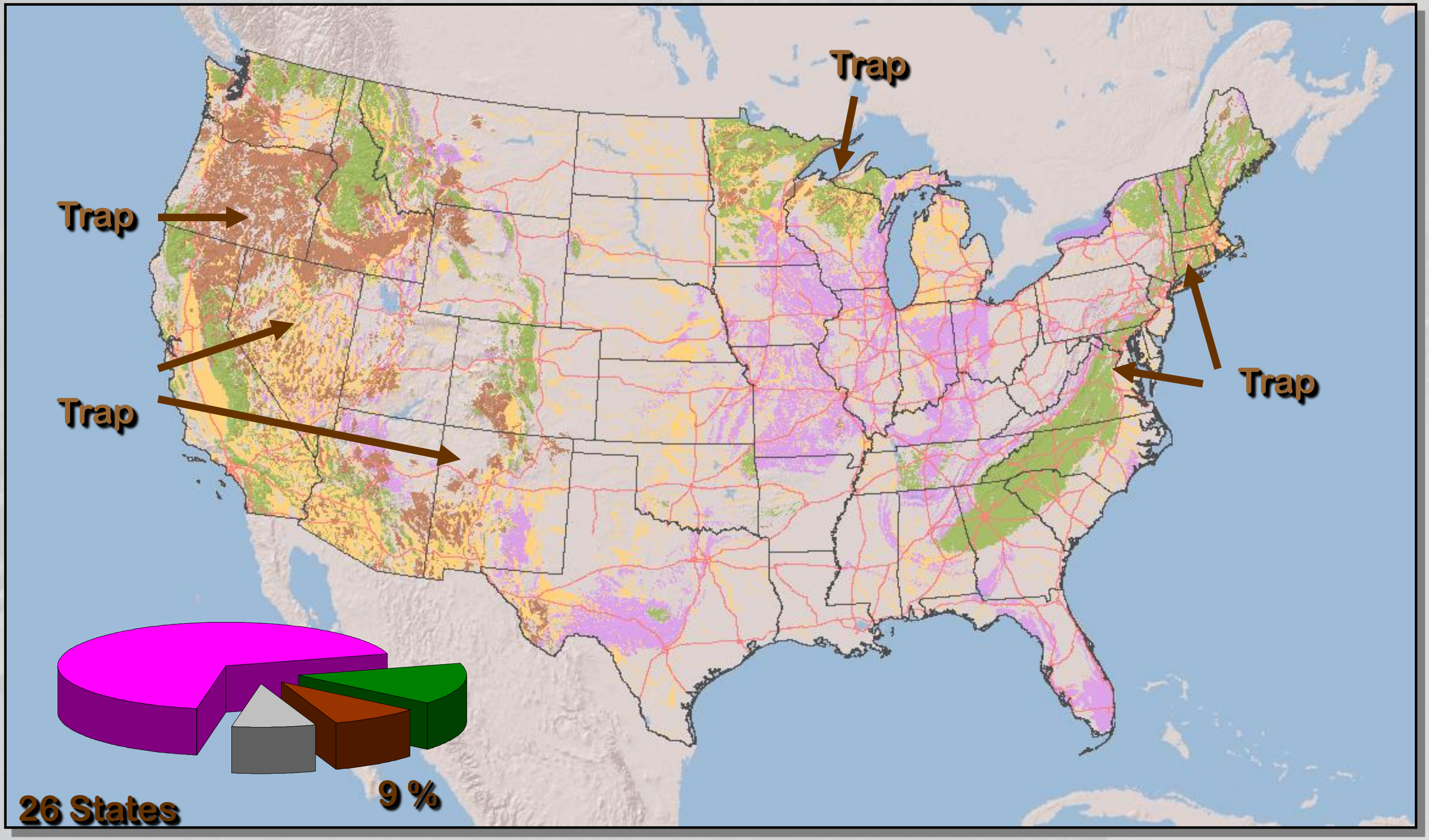
Trap



Trap – Dark, fine-grained, igneous – basalt, diabase

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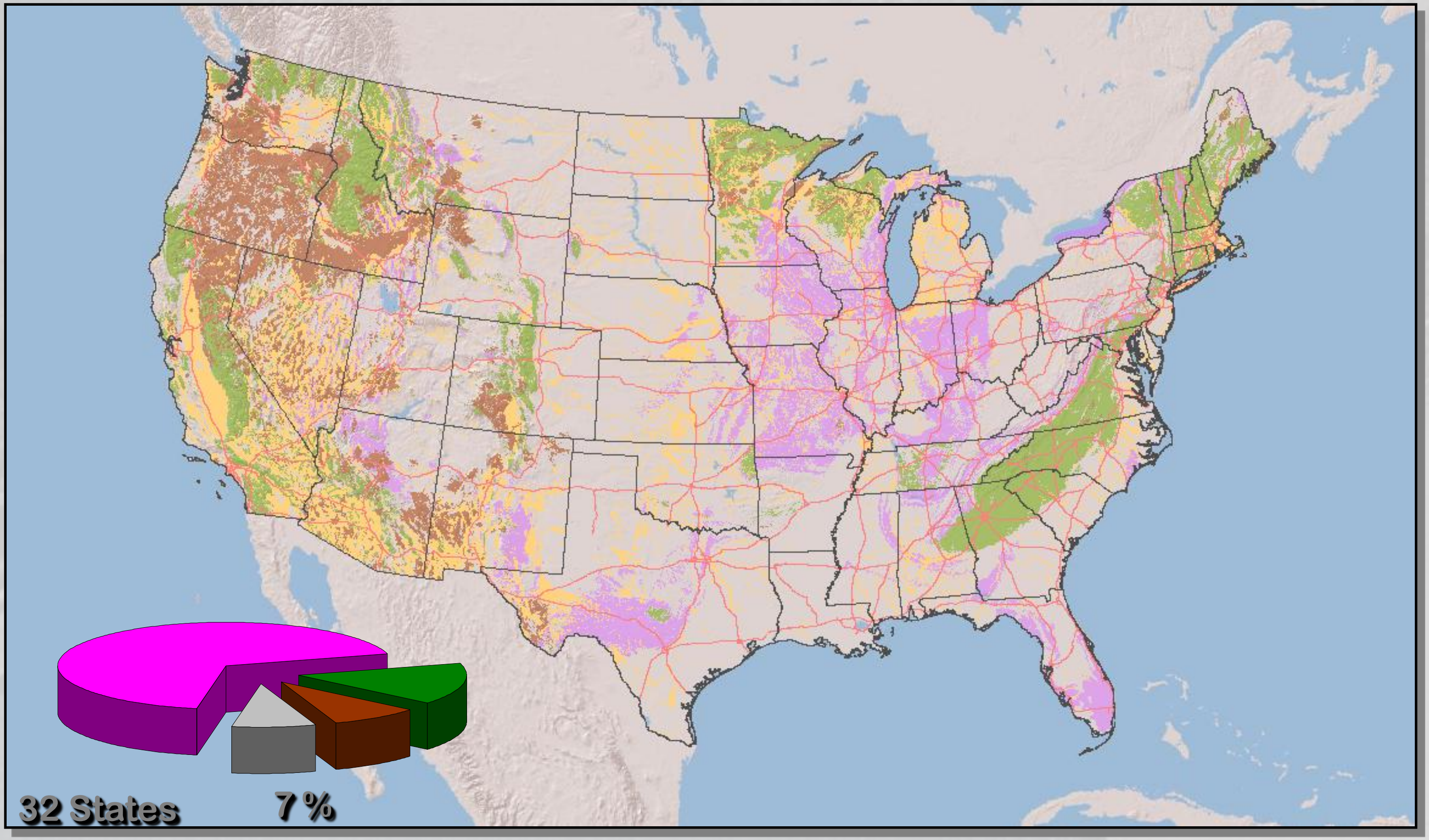
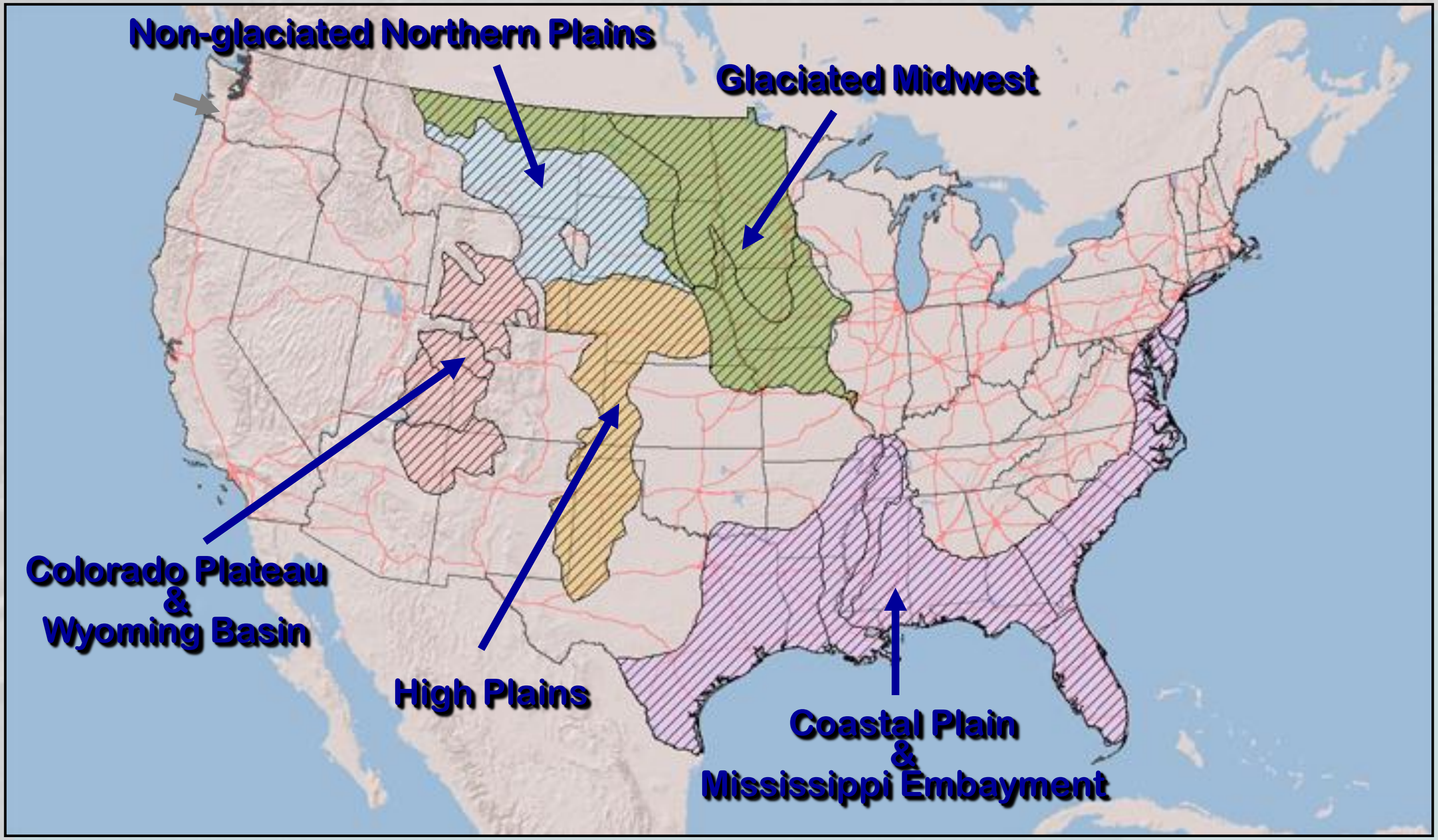
Other

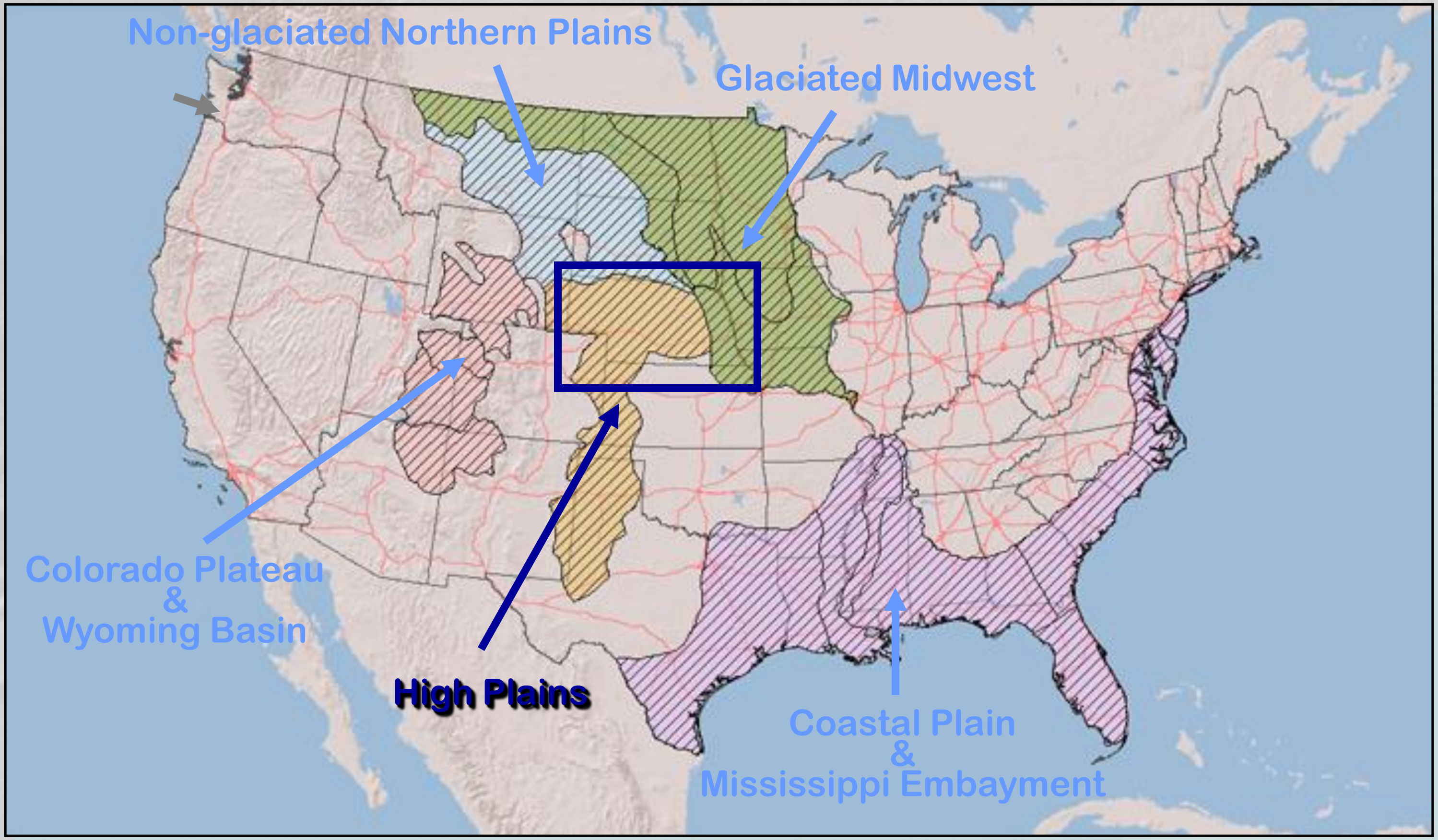


Other – Sandstone, quartzite, chert, shells, cinder, scoria, clinker, and other rock.

Where aggregate is in limited occurrence



High Plains - Nebraska



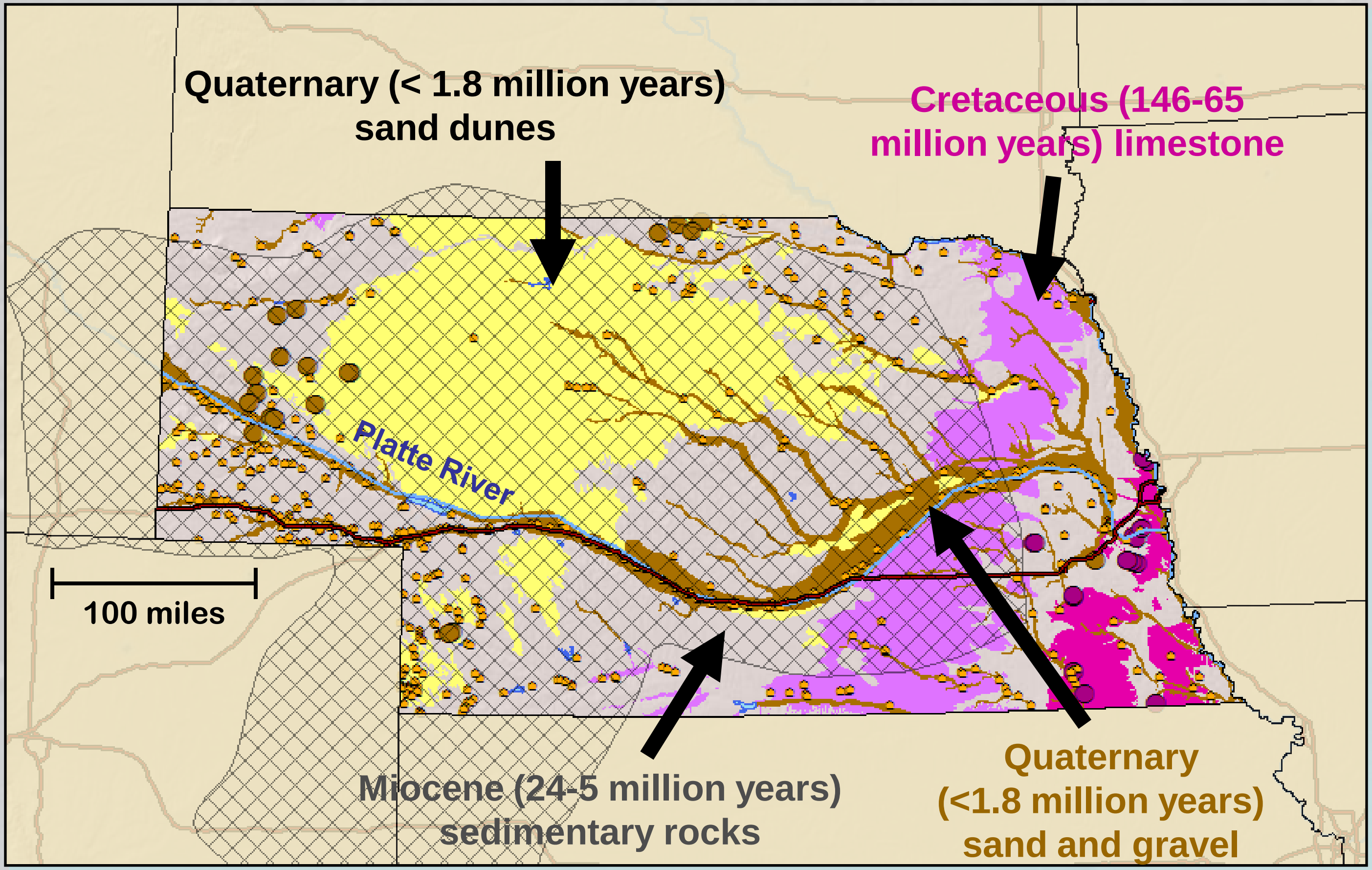
High Plains - Nebraska

Sand Hills

Broad valleys

Photographs from the U.S. Geological Survey.

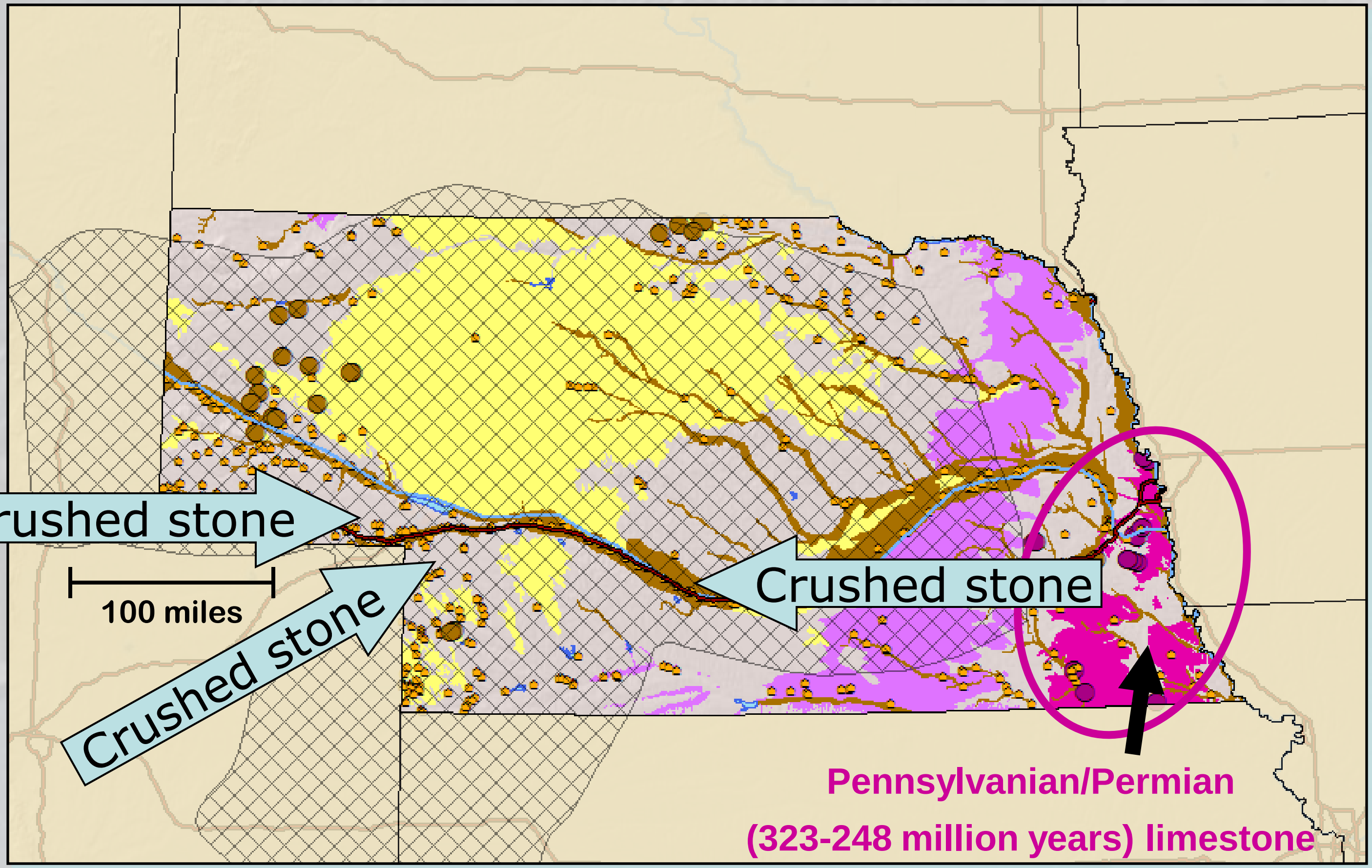
Geology



Limestone   Sandstone   Sand & gravel   High Plains Province

Nebraska Conservation and Survey Division - Active aggregate operations

Crushed stone sources



NCSD - Active aggregate operations

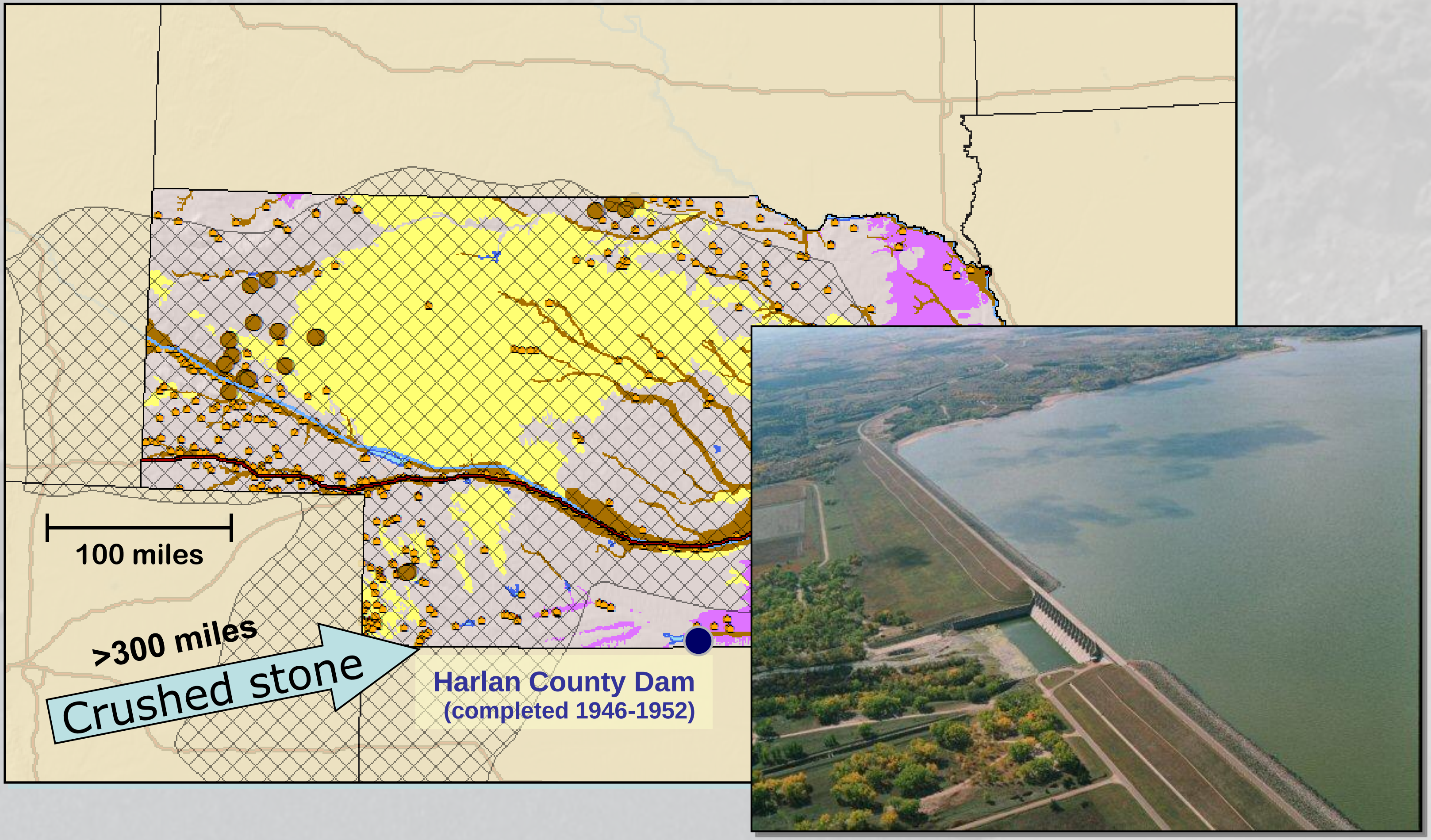
Limestone

Sandstone

Sand & gravel

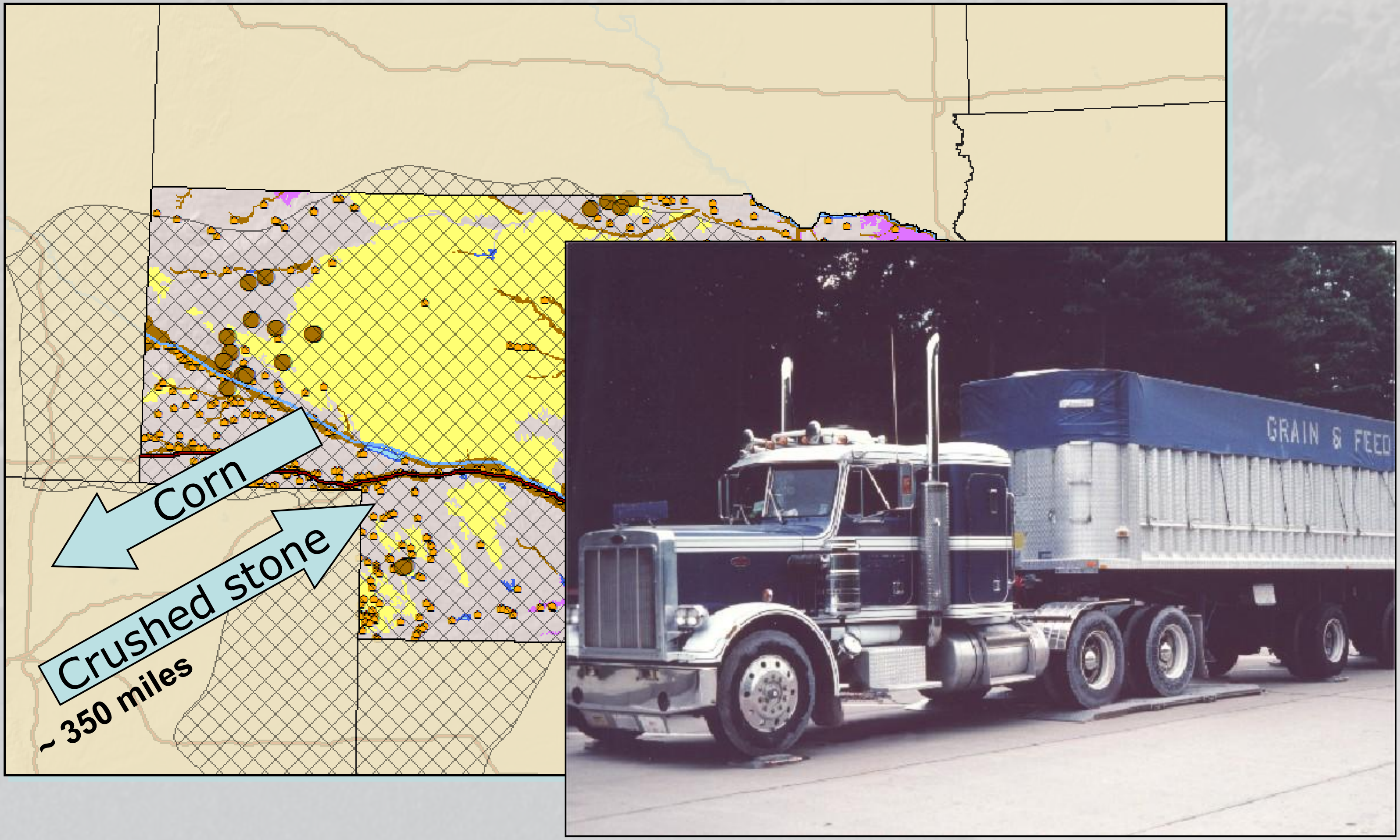
High Plains Province

Special requirements



Photograph from the U.S. Army Corps of Engineers.

Backhaul



Photograph from the Federal Highway Administration.

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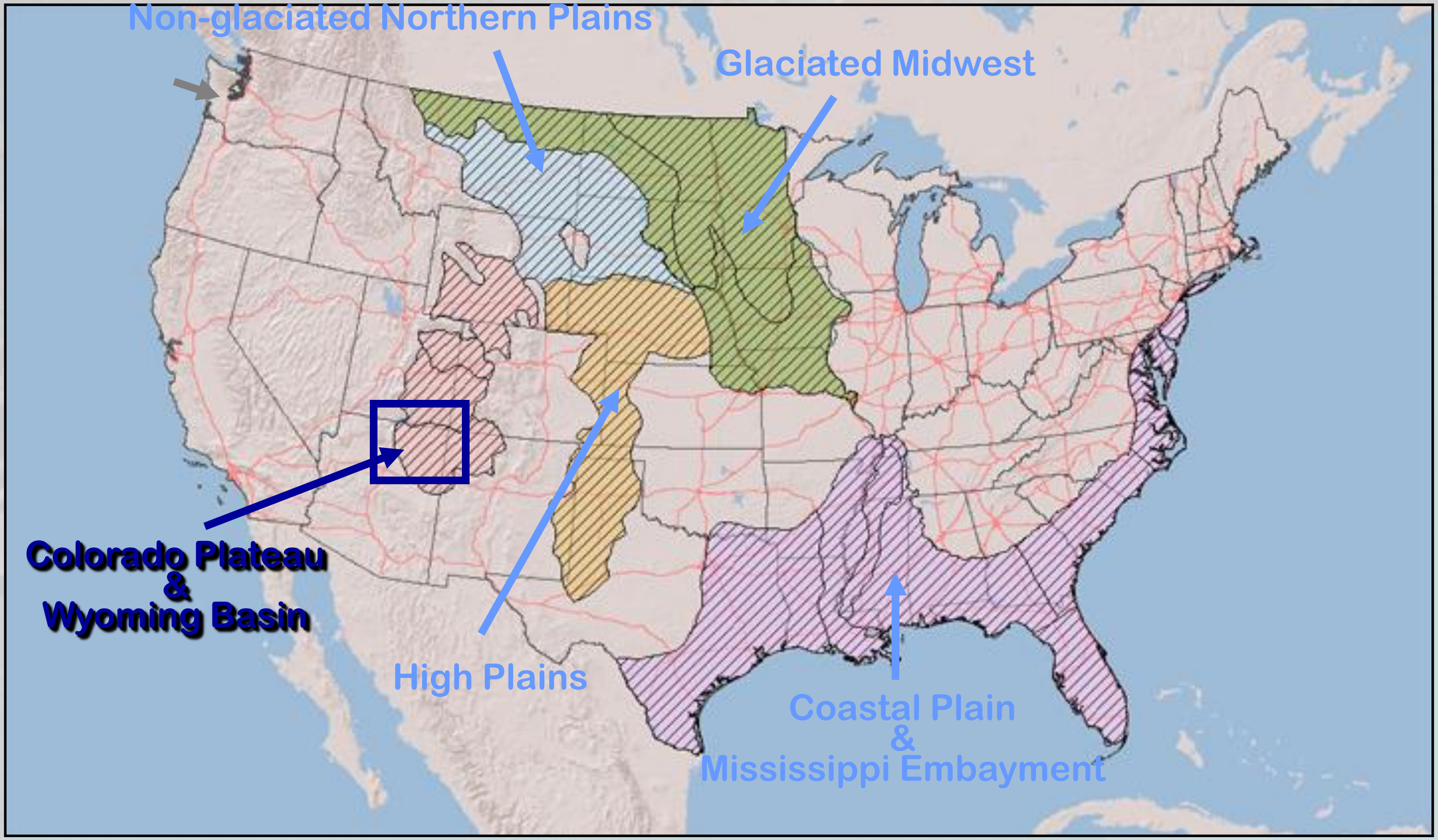
Colorado Plateau and Wyoming Basin Northeastern Arizona



Colorado Plateau & Wyoming Basin
Northeastern Arizona

High desert

Photograph from the U.S. Geological Survey.

Buttes and steep cliffs

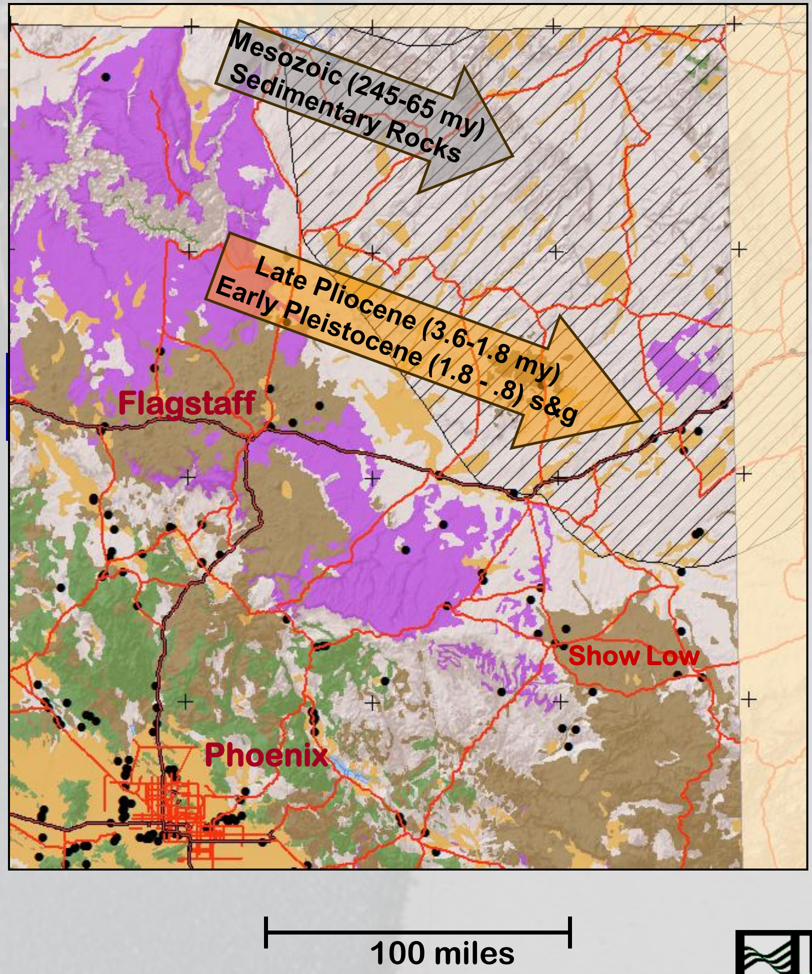
Photograph from the U.S. National Park Service.

Geology

Limestone
Granite
Trap
Sand & gravel (s&g)

- Material sources that have completed the Arizona Department of Transportation (ADOT) Environmental Analysis Process

Area of limited aggregate resources

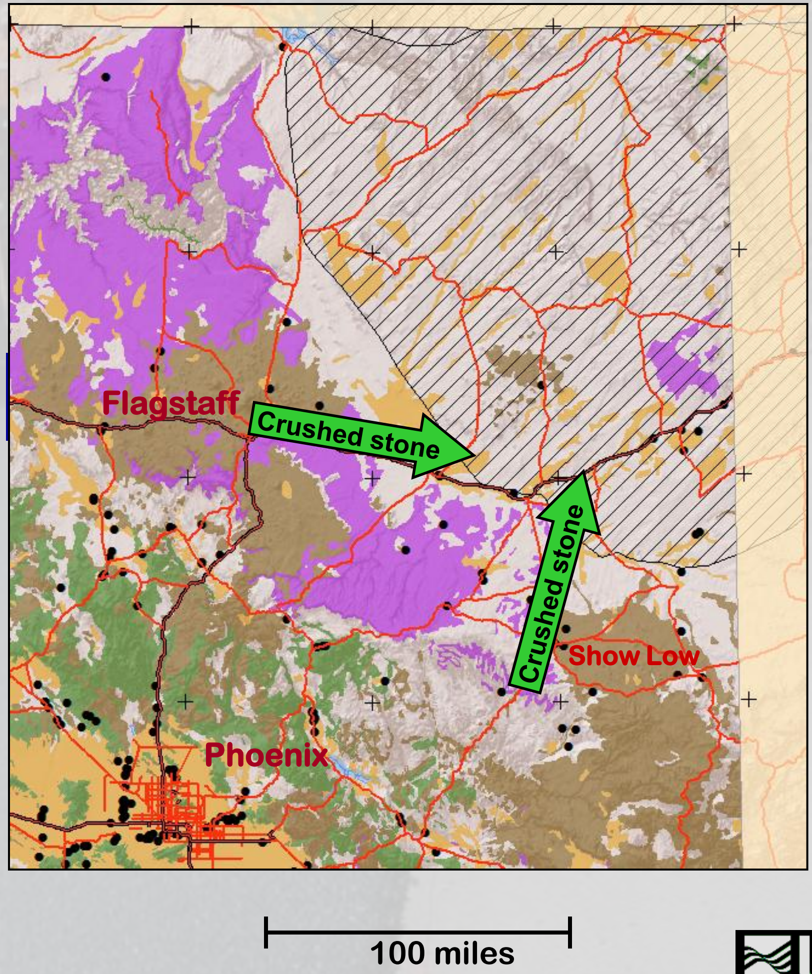


Crushed stone sources

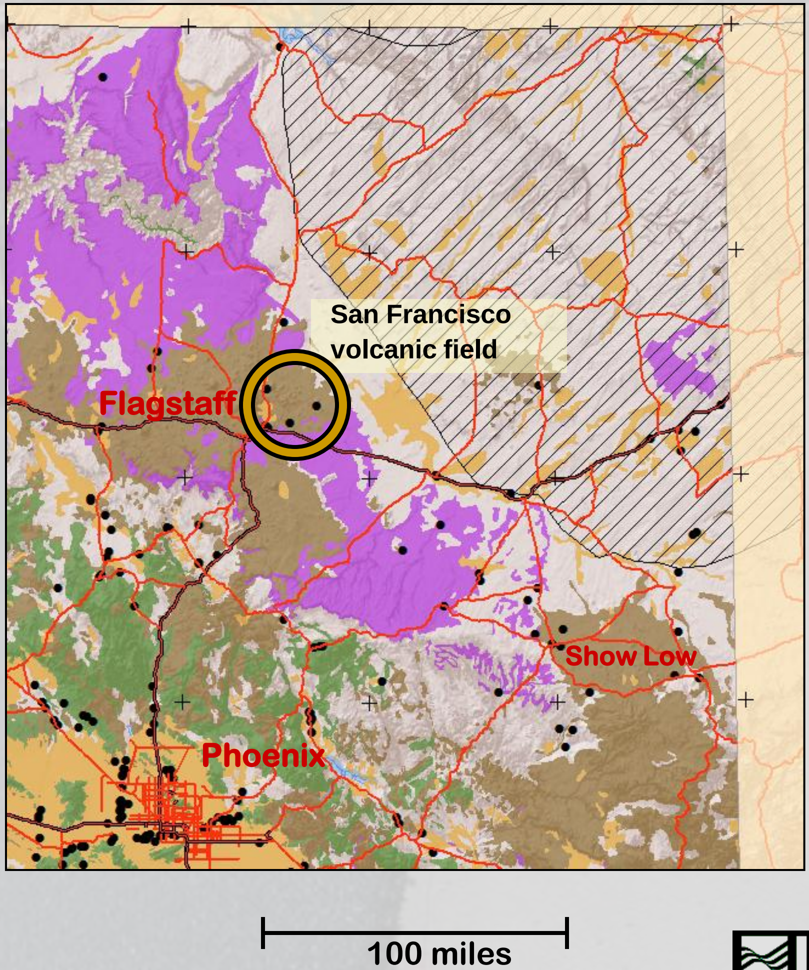
Limestone
Granite
Trap
Sand & gravel (s&g)

- Material sources that have completed the Arizona Department of Transportation (ADOT) Environmental Analysis Process

Area of limited aggregate resources

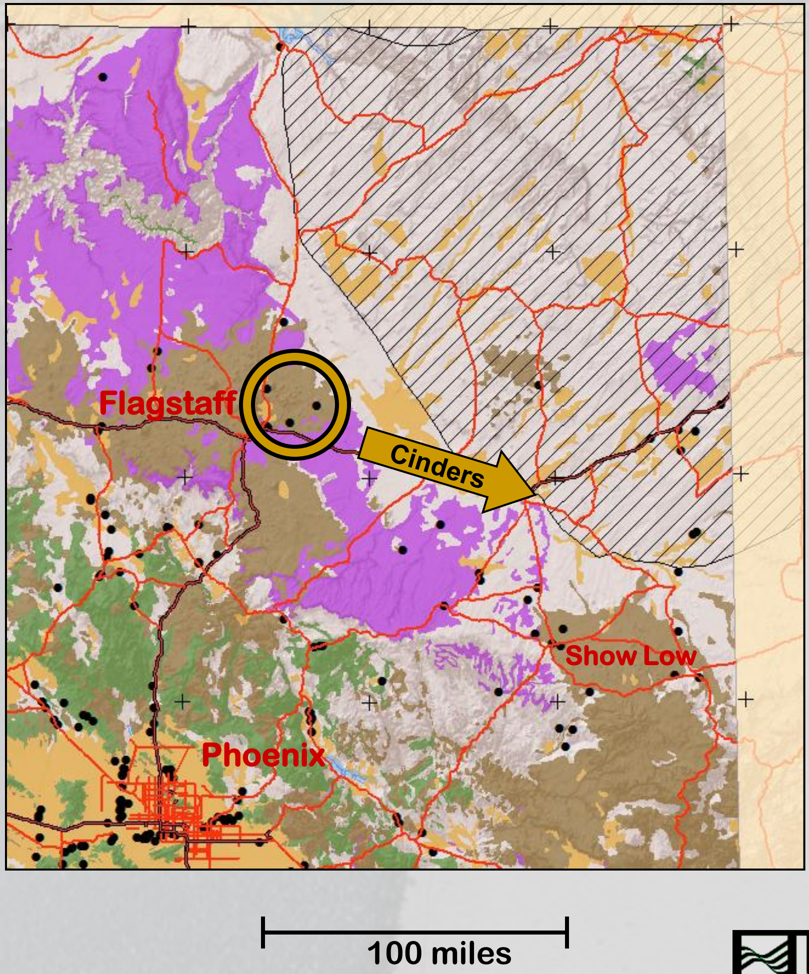


Marginal material - Cinders



Photographs from the U.S. Geological Survey.

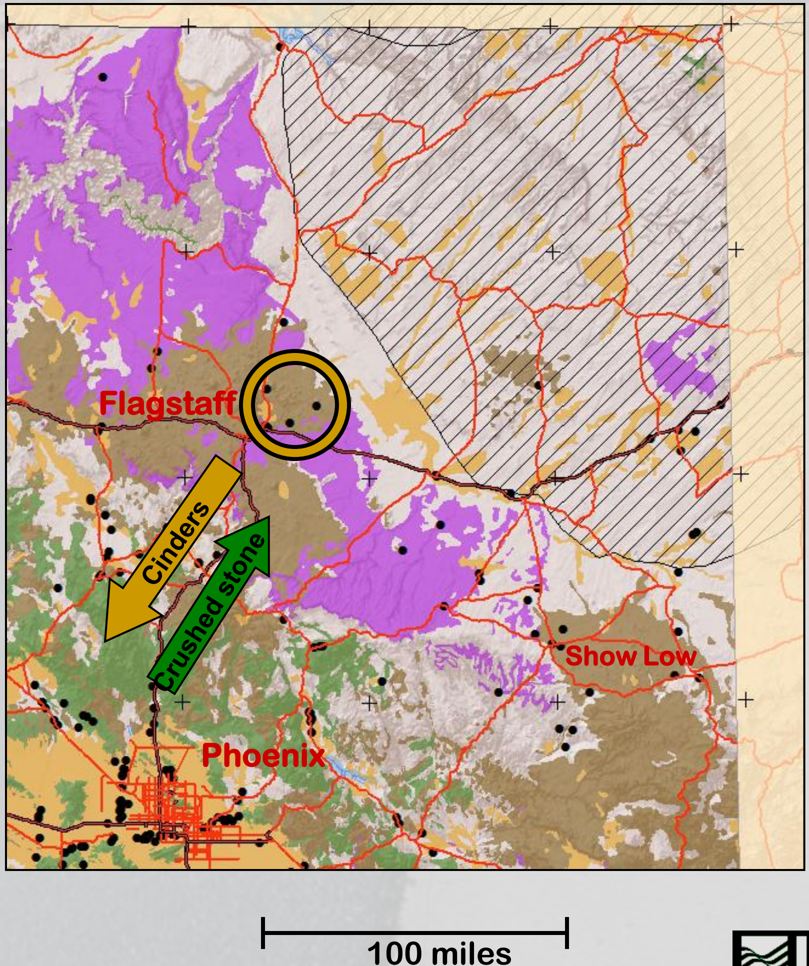
Uses of marginal material



- Block
- Road base
- Roads
- Snow & ice control
- Driveways
- Landscaping
- Leach lines
- Corrals
- Yards

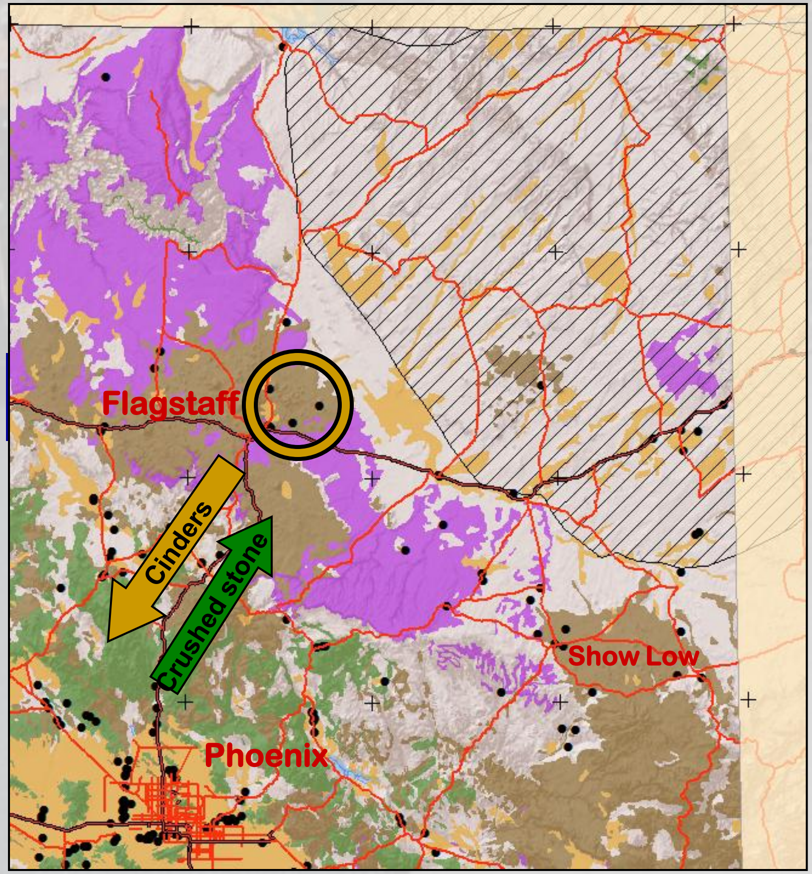
Photograph from the U.S. Geological Survey.

Backhaul



Photograph from the U.S. Geological Survey.

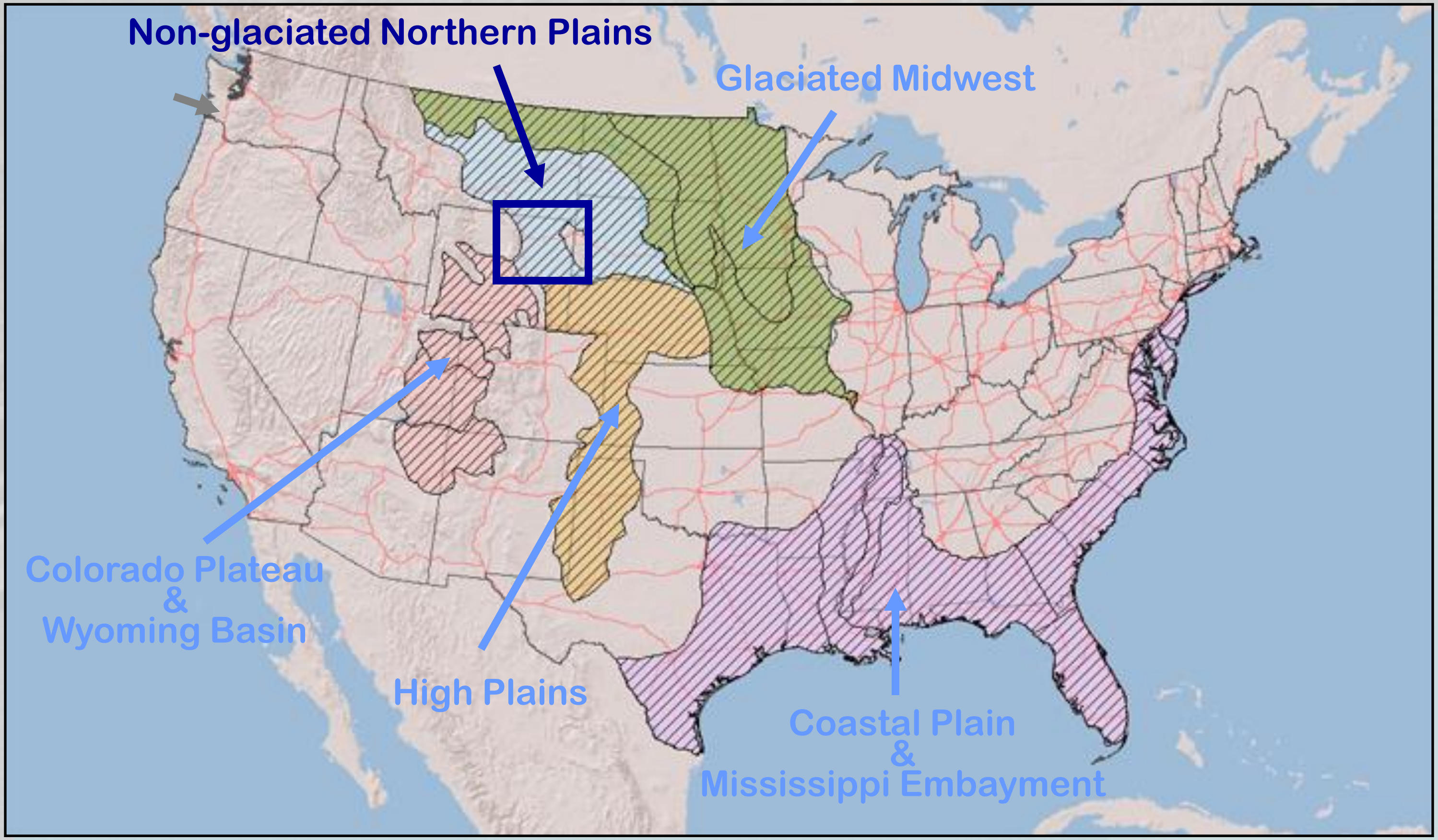
Backhaul



Cost of aggregate transport in congested urban areas or mountainous areas can be three to four times as expensive as open-highway transportation.

Photograph from the U.S. Geological Survey.

Non-Glaciated Northern Plains Northeastern Wyoming



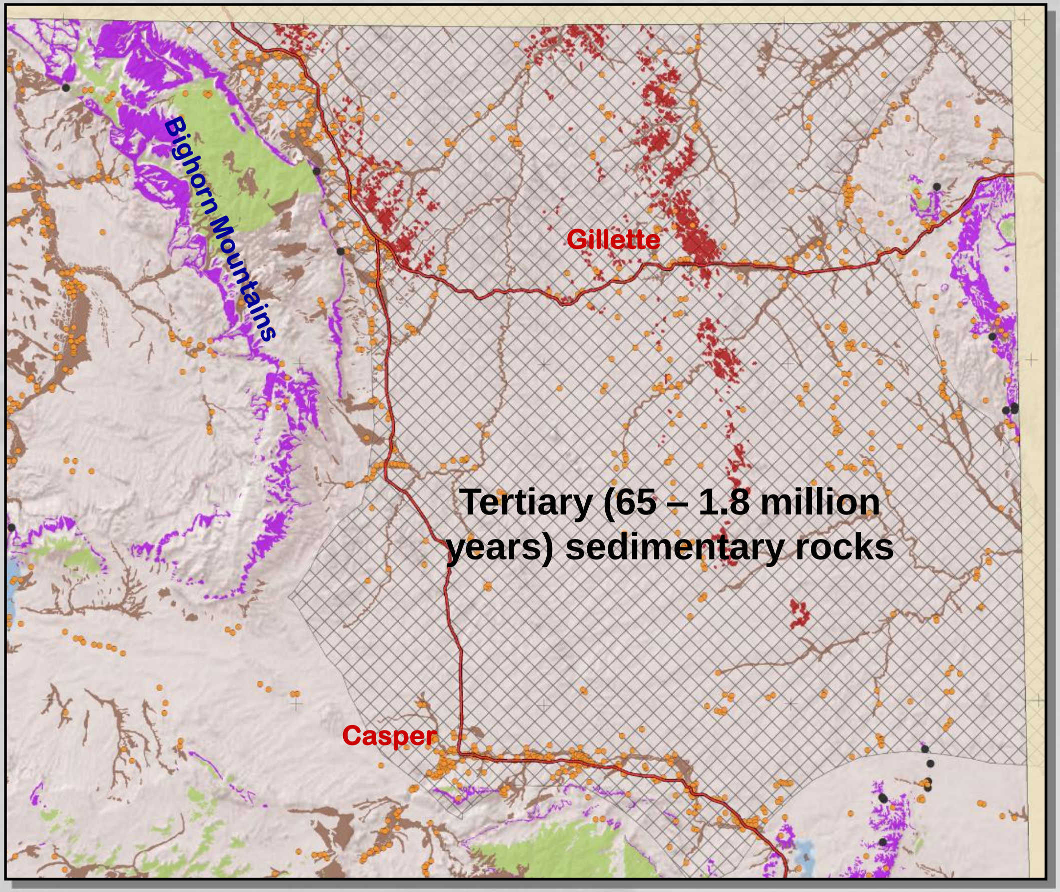
Non-glaciated Northern Plains Northeastern Wyoming

Rolling plains

Short grass prairie

Photographs from the U.S. Bureau of Land Management.

Geology



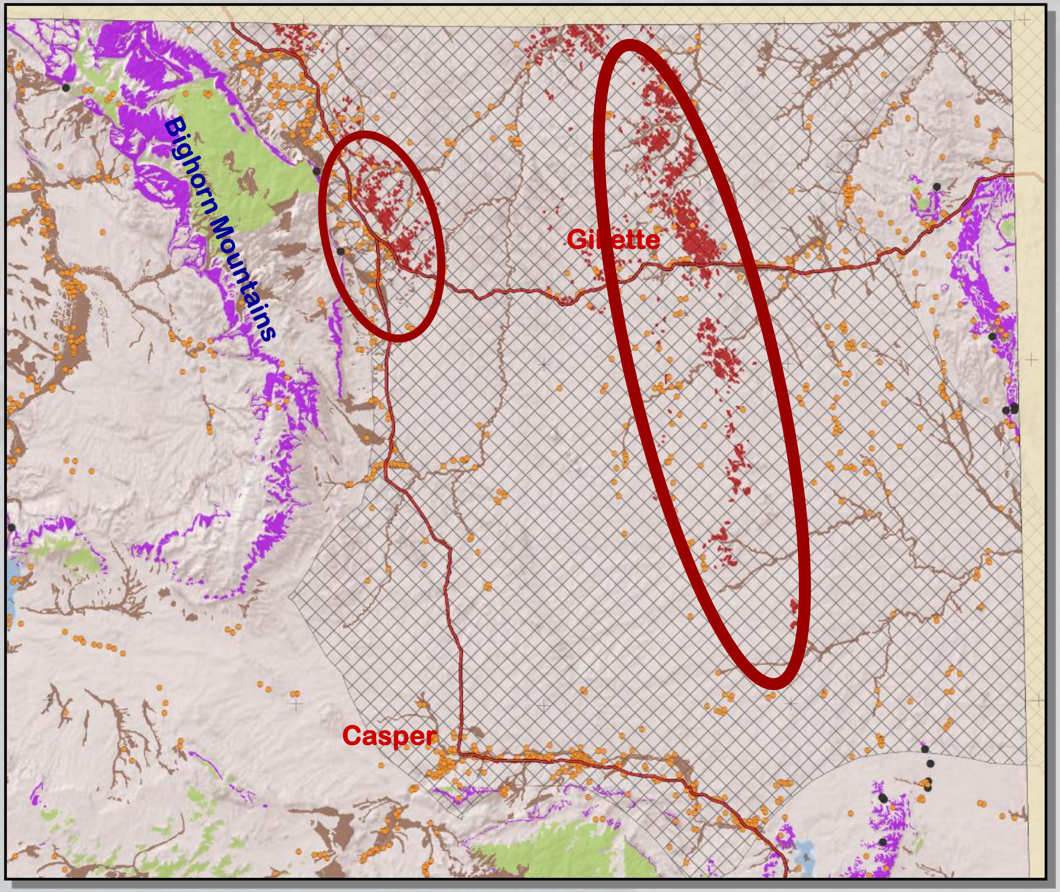
- Active crushed stone operation
- Active sand & gravel operation
- Areas of limited aggregate resources

Data from Wyoming Geological Survey (Harris, 2004)

100 miles

Unconventional material - Clinker

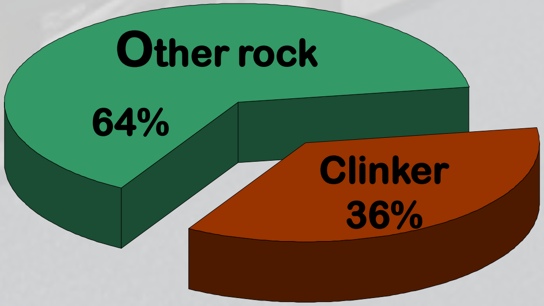
Clinker
(scoria, porcellanite, red dog)

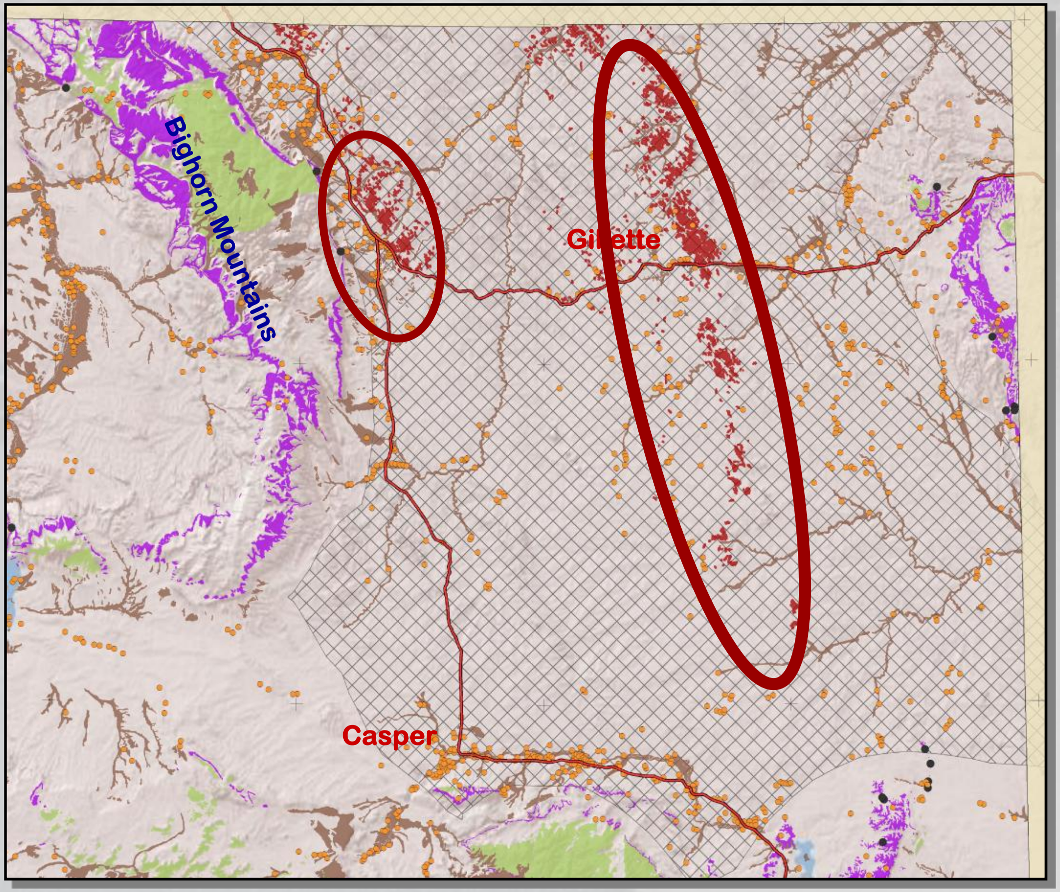


100 miles

Photograph from the Wyoming Geological Survey.

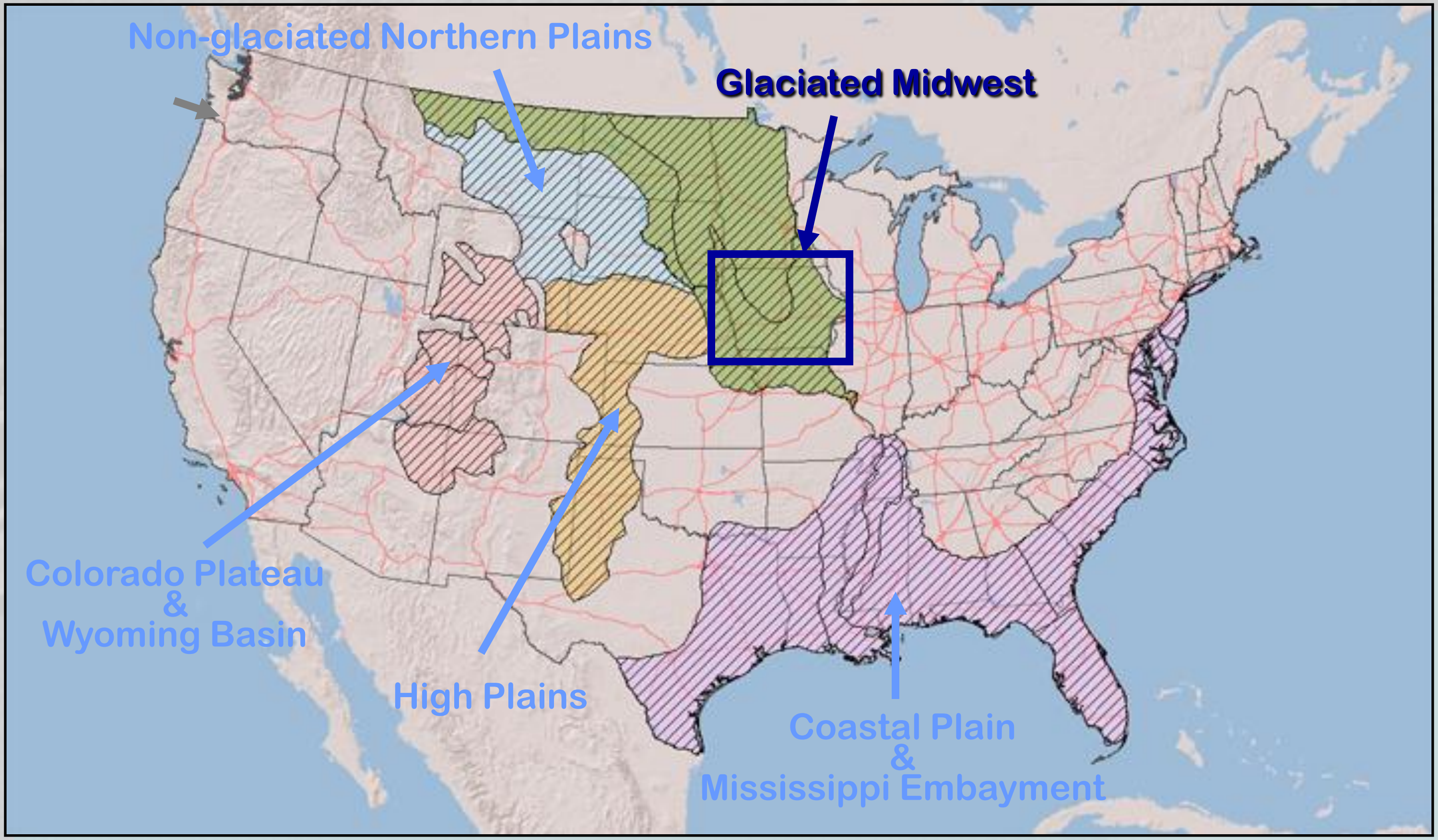
Unconventional material - Clinker





100 miles

Glaciated Midwest - Iowa



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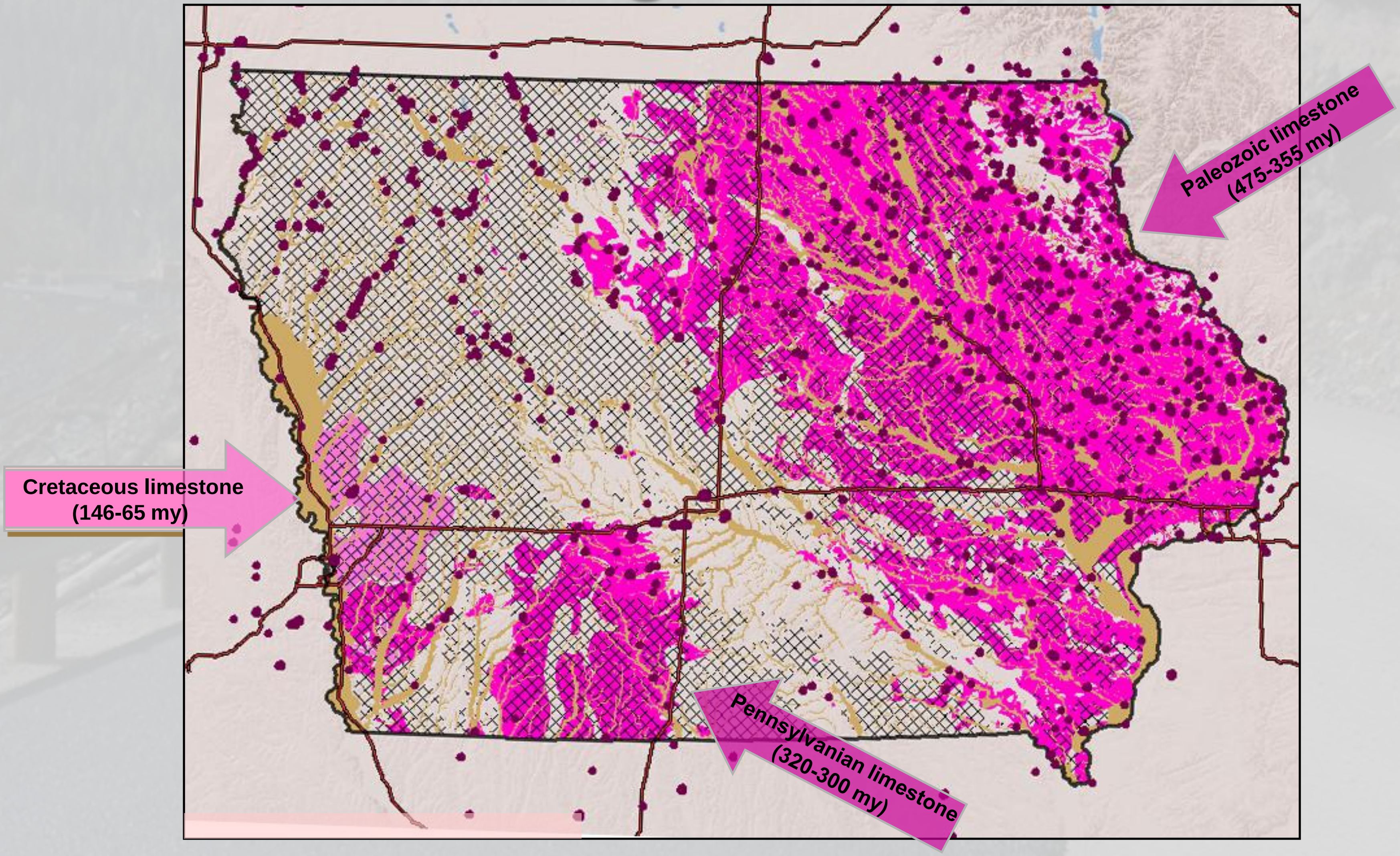
Glaciated Midwest - Iowa

Loess hills

Glaciated plains

Photographs from the U.S. Geological Survey.

Thick glacial cover



• Iowa Dept. of Transportation approved sources

> 150 ft overburden

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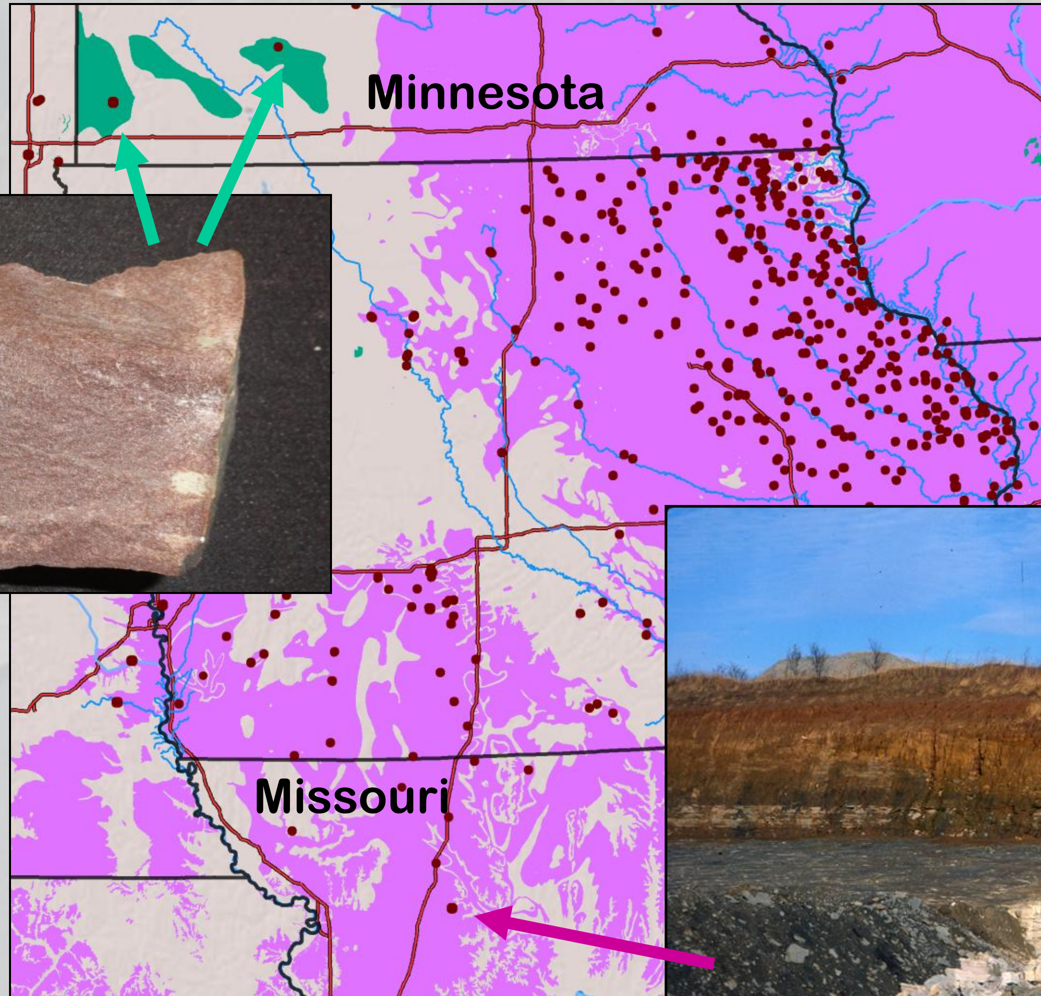
Interstate Supply



Photographs from the U.S. Geological Survey.

Overburden thin enough to mine aggregate)

- Iowa Dept. of Transportation approved sources

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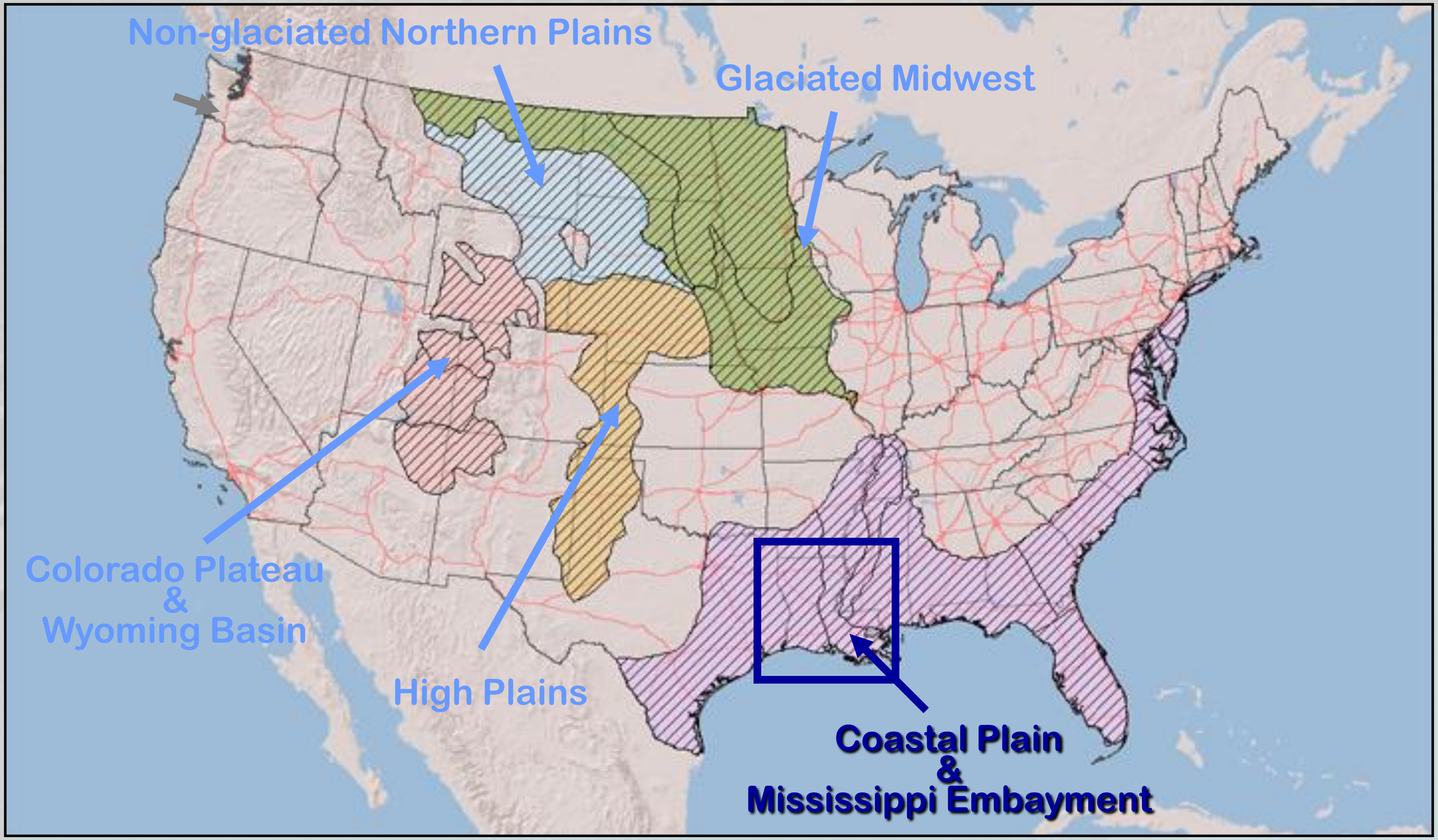
Coastal Plain & Mississippi Embayment
Louisiana



Coastal Plain & Mississippi Embayment
Louisiana

Flood plains

Photograph from the U.S. Army Corps of Engineers.

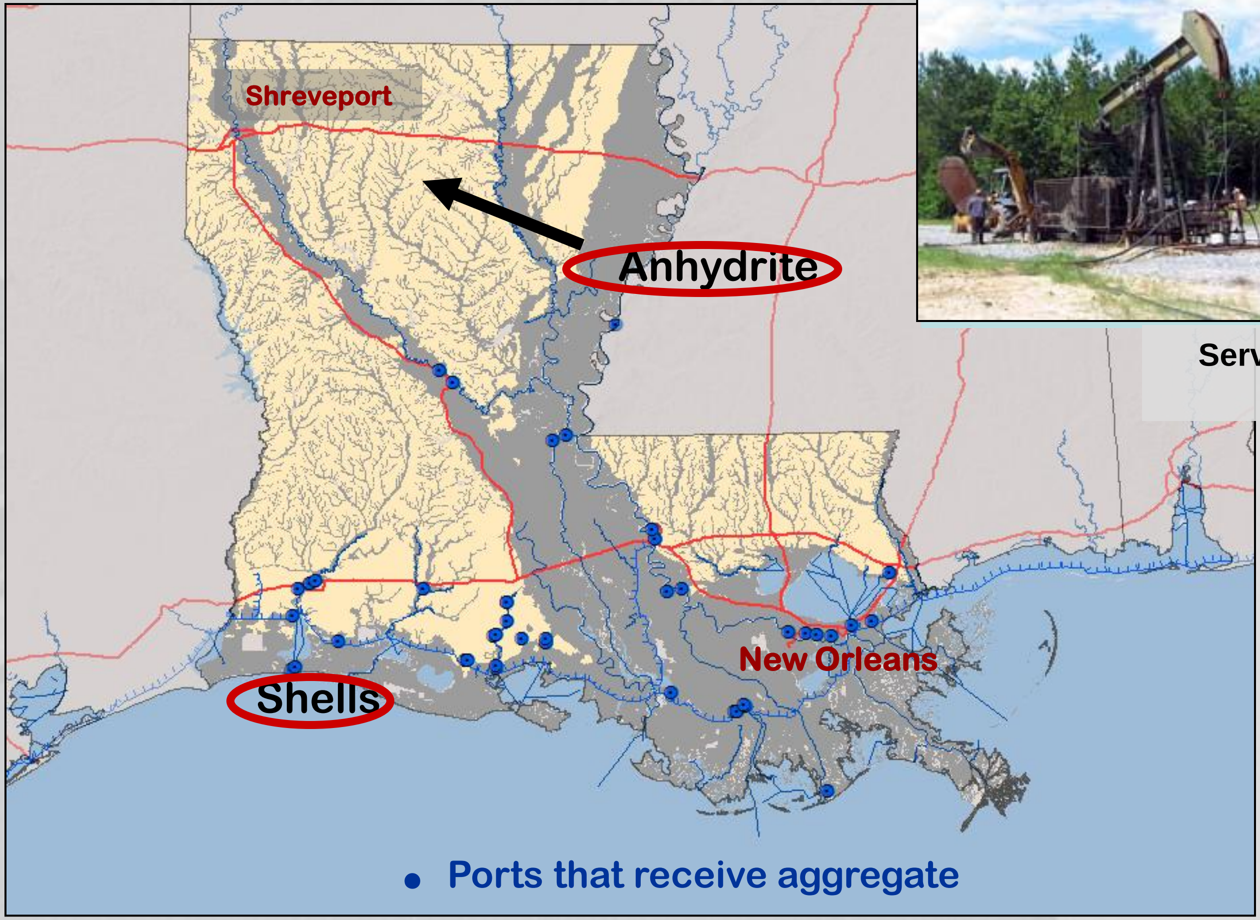
Swamps

Photograph from the U.S. Geological Survey.

Pine barrens

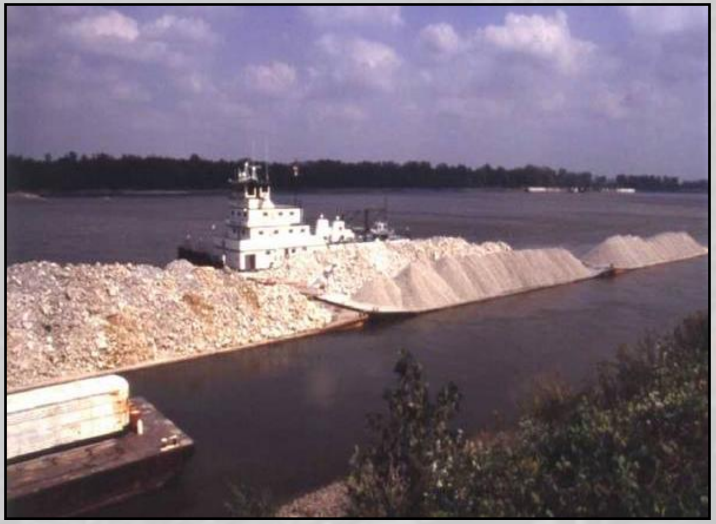
Photograph from the U.S. Geological Survey.

Unconventional Material



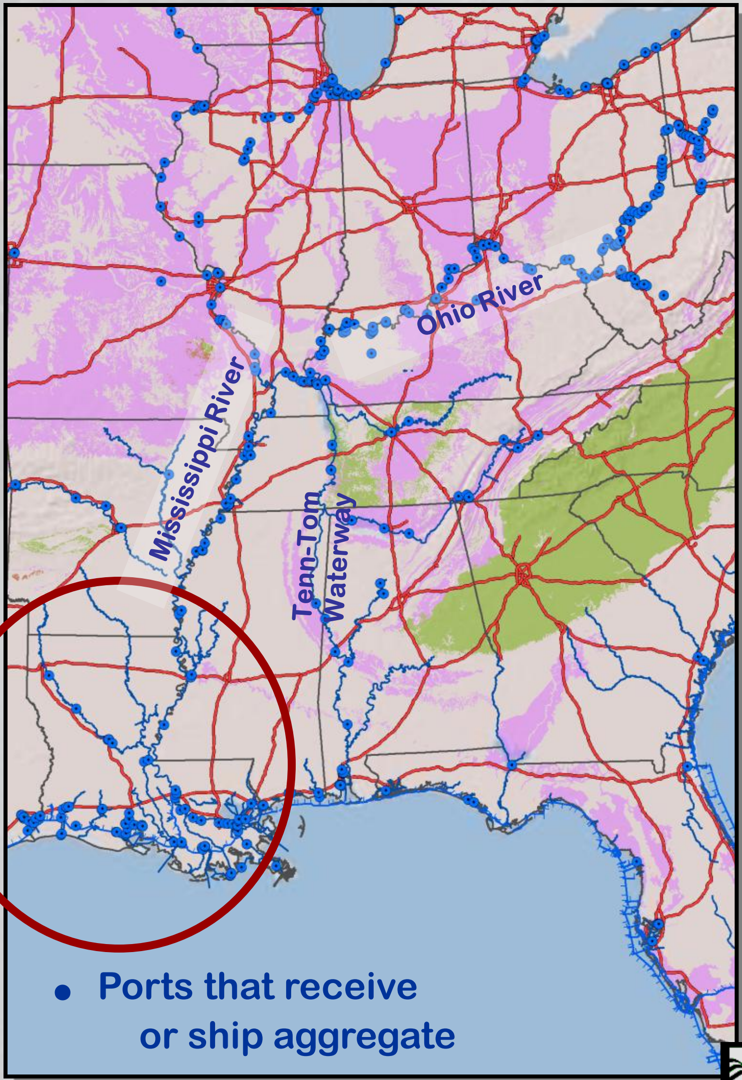
Service road paved with anhydrite

Supply by water transport

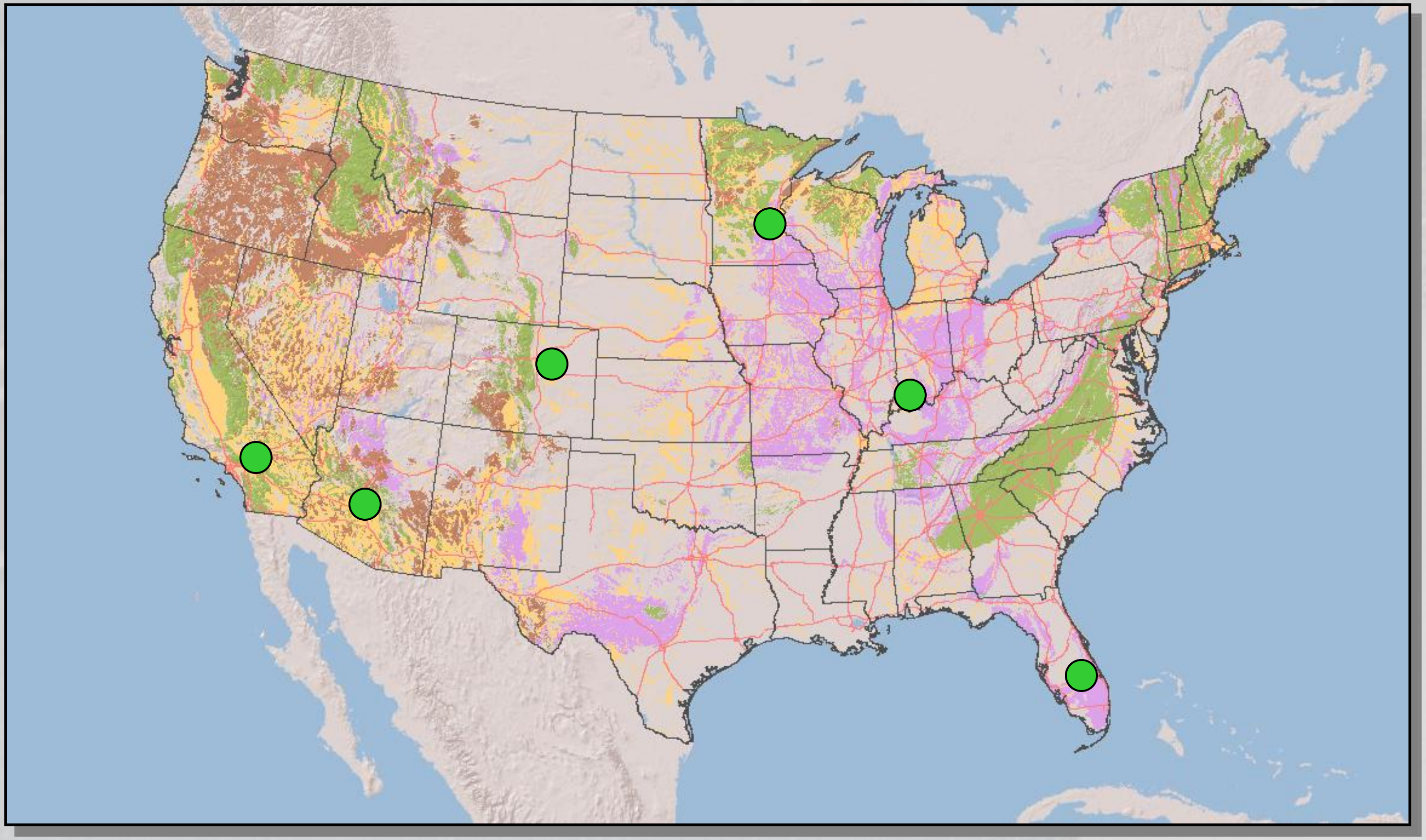


Photograph from the U.S. Army Corps of Engineers

Photograph from the U.S. Geological Survey.



Quality, Societal, and Environmental Issues Limiting Aggregate Availability



Locations of case-study areas

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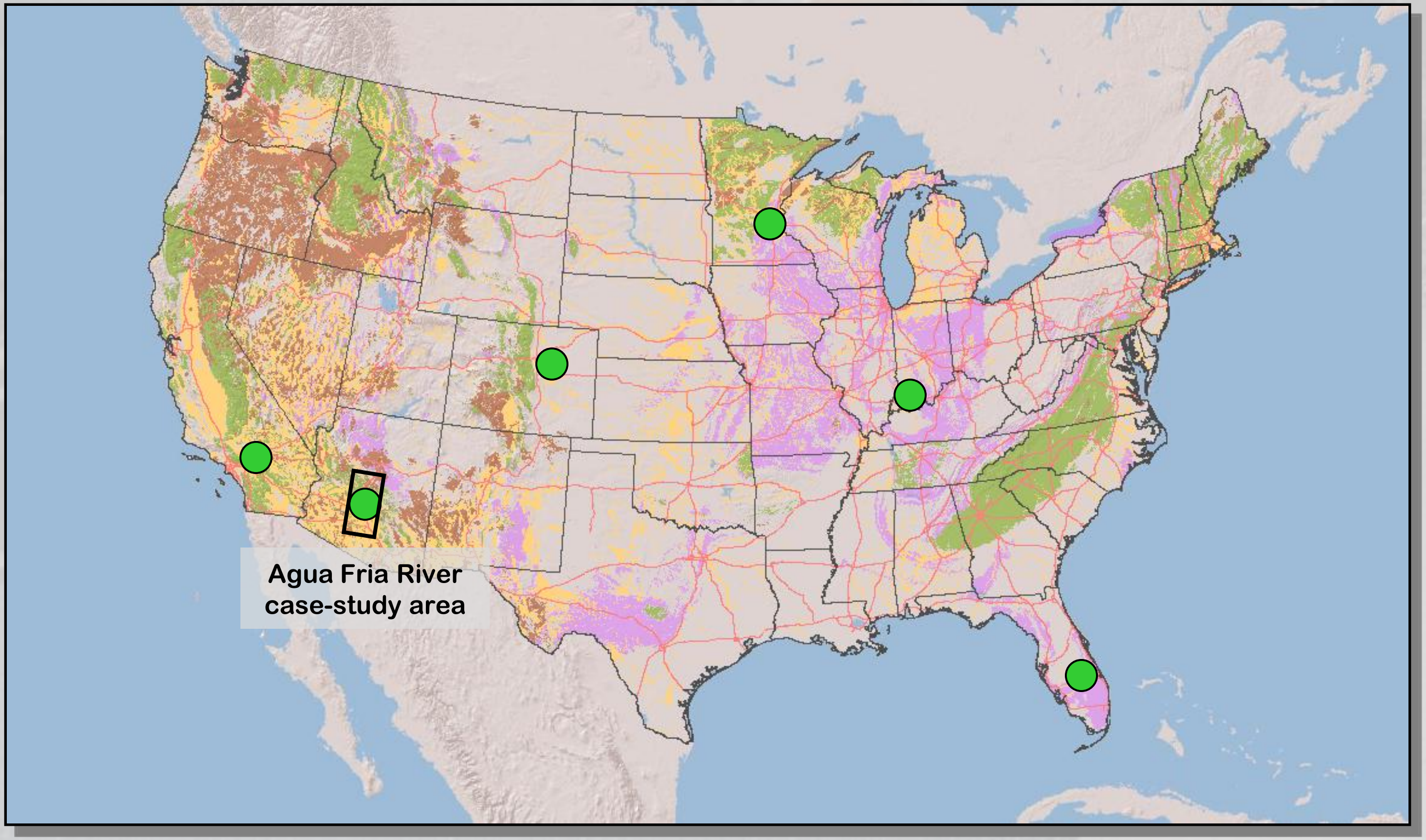
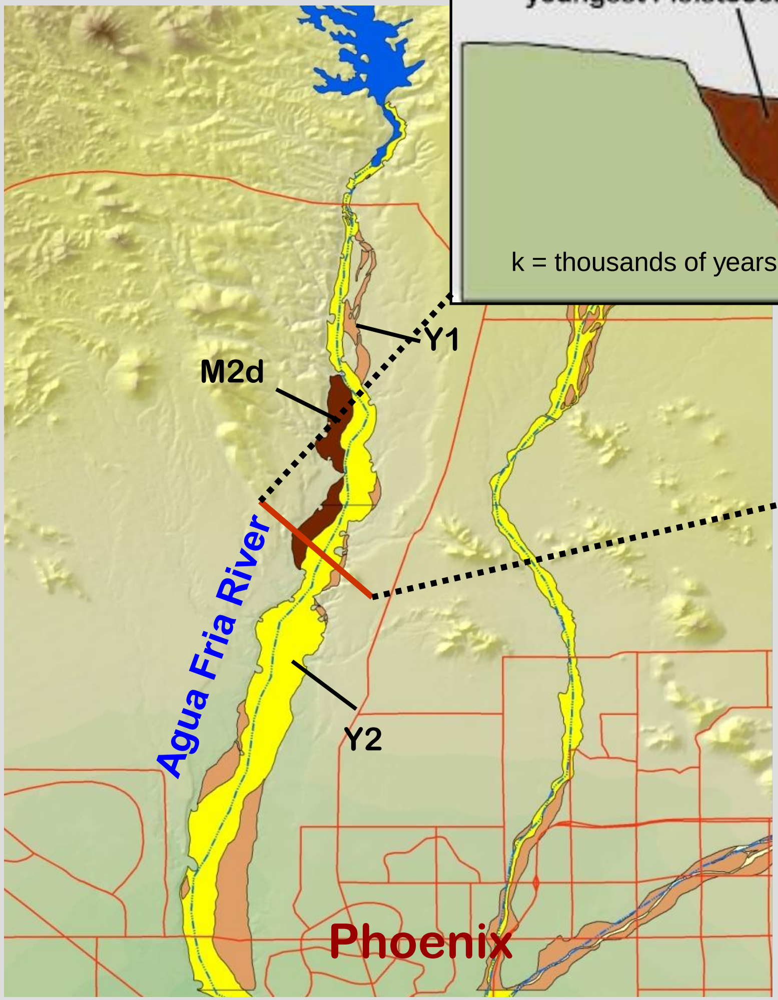
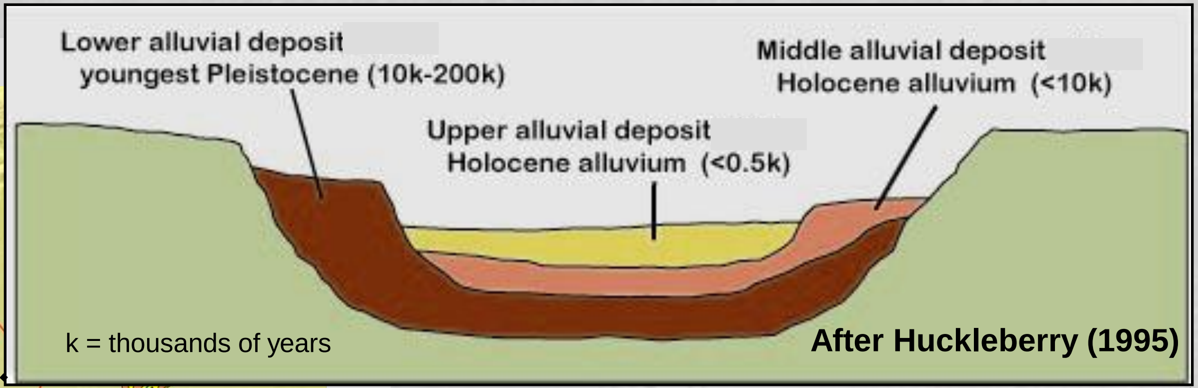
Quality Issues
Agua Fria River - Phoenix, Arizona

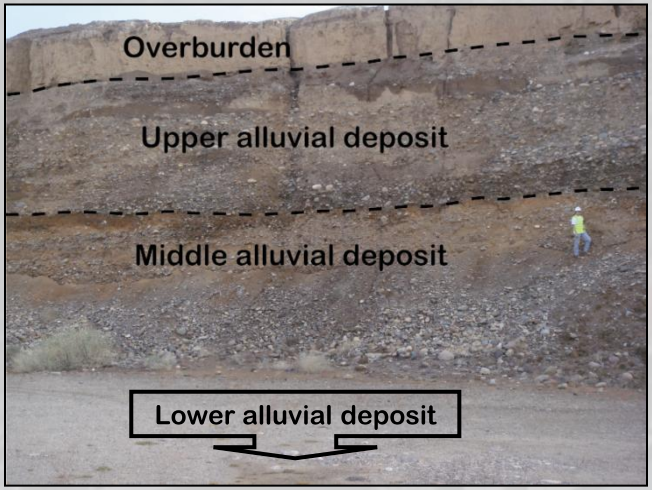


Geology


Y1
M2d
Agua Fria River
Y2
Phoenix


Lower alluvial deposit
youngest Pleistocene (10k-200k)
Middle alluvial deposit
Holocene alluvium (<10k)
Upper alluvial deposit
Holocene alluvium (<0.5k)
k = thousands of years
After Huckleberry (1995)

Engineering properties vs depth



- Weathering increases with depth (age)
- Quality decreases as weathering increases

Increased weathering

Sample Location	*Specific Gravity (ASTM C 127)	*Absorption (ASTM C 127)	*Micro-Deval Abrasion Grading B (ASTM D 6928)
Igneous rocks			
Upper alluvial deposit	2.67	0.80%	12%
Middle alluvial deposit	2.62	1.40%	13%
Lower alluvial deposit	2.61	1.00%	16%
Metamorphic rocks			
Upper alluvial deposit	2.81	0.50%	12%
Middle alluvial deposit	2.79	1.00%	12%
Lower alluvial deposit	2.70	1.20%	16%
Tertiary rocks			
Upper alluvial deposit	2.62	2.50%	24%
Middle alluvial deposit	2.59	3.90%	30%
Lower alluvial deposit	2.51	4.00%	35%

* American Society for Testing and Materials, 2011

Photograph from the U.S. Geological Survey.

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Engineering properties vs depth

on	Specific Gravity (ASTM C 127)	Absorption (ASTM C 127)	Micro-Deval Abrasion Grading B (ASTM D 6928)
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Upper alluvial deposit	2.62	2.50%	24%
Middle alluvial deposit	2.59	3.90%	30%
Lower alluvial deposit	2.51	4.00%	35%

- **Weathered tertiary rocks generally lack strength**

Photograph from the U.S. Geological Survey.

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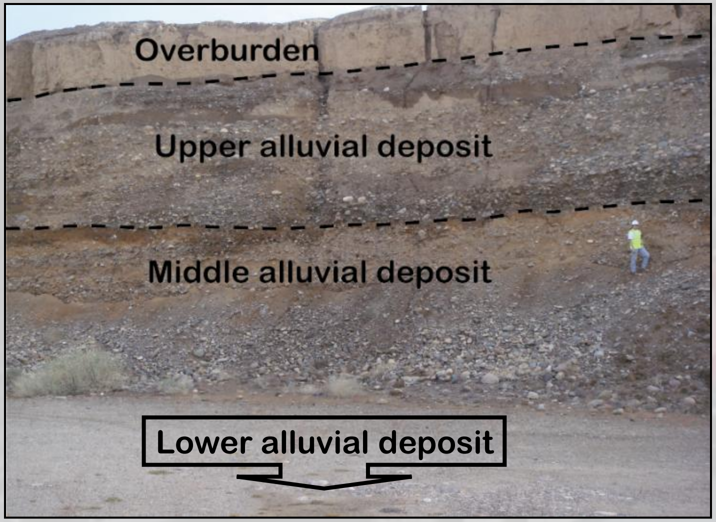
Engineering properties vs depth



- Processing
- Blending

Increased weathering

Sample Location	Specific Gravity (ASTM C 127)	Absorption (ASTM C 127)	Micro-Deval Abrasion Grading B (ASTM D 6928)
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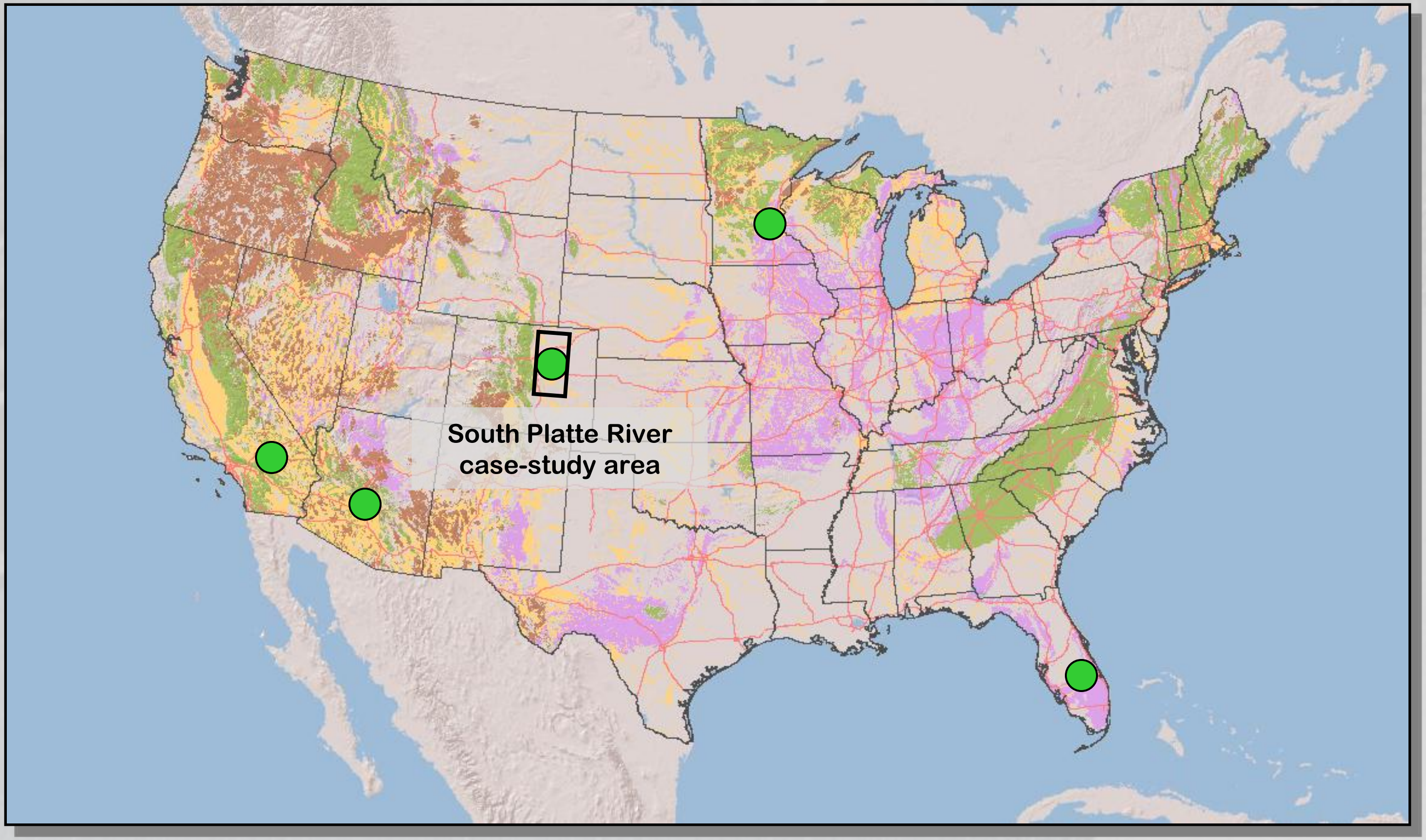
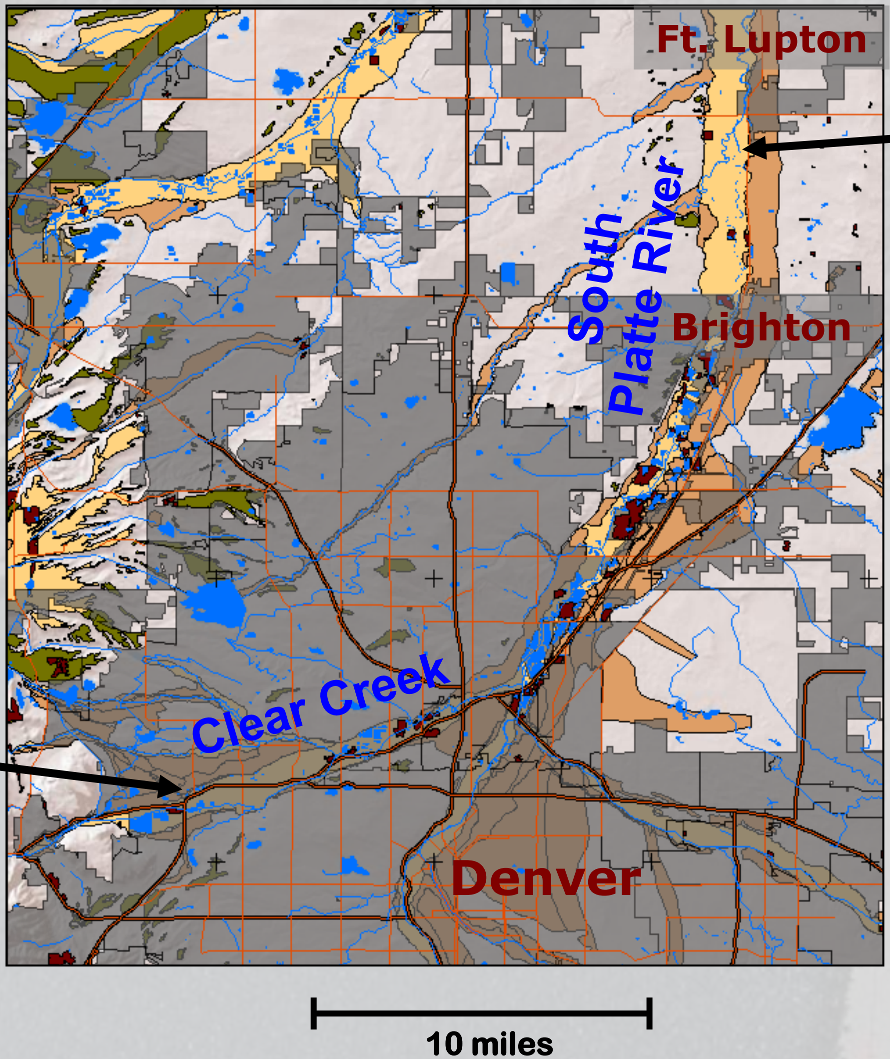
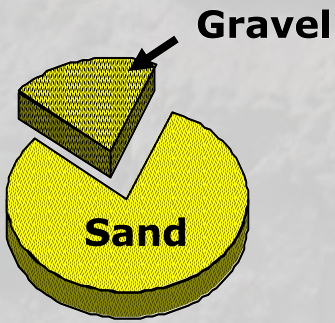
Quality Issues
South Platte River - Denver, Colorado

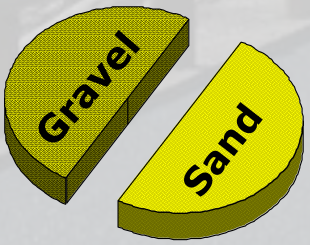


Alluvial gravels

Pits/quarries
Built-up areas
High-quality sand & gravel
Low-quality sand & gravel
Water







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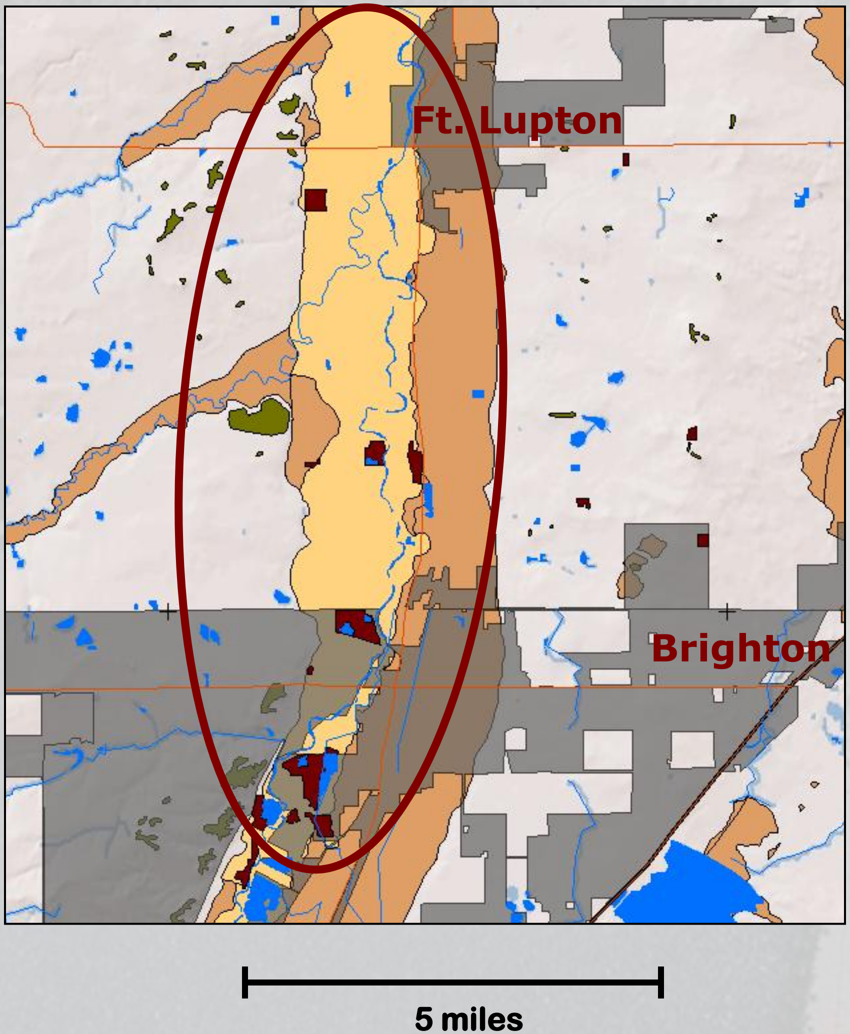
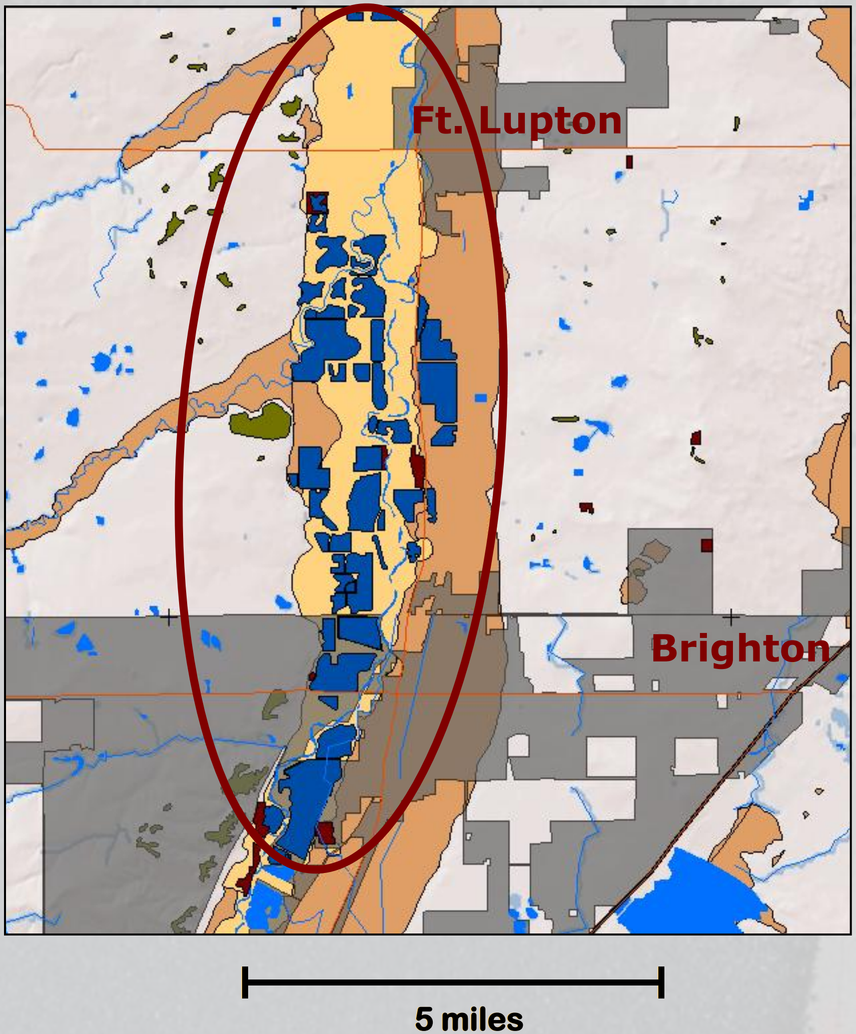
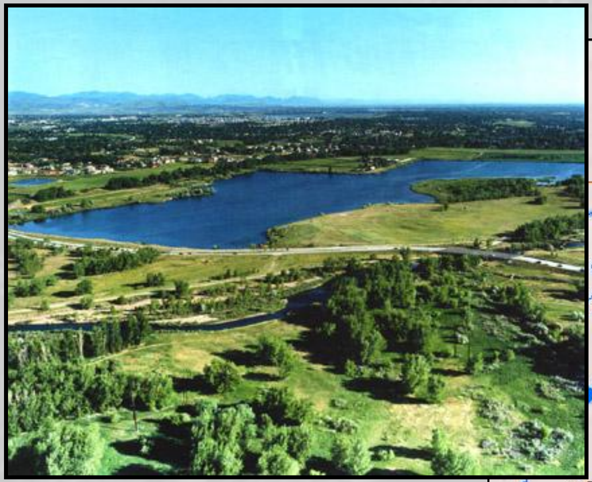
Gravel operations - 2010



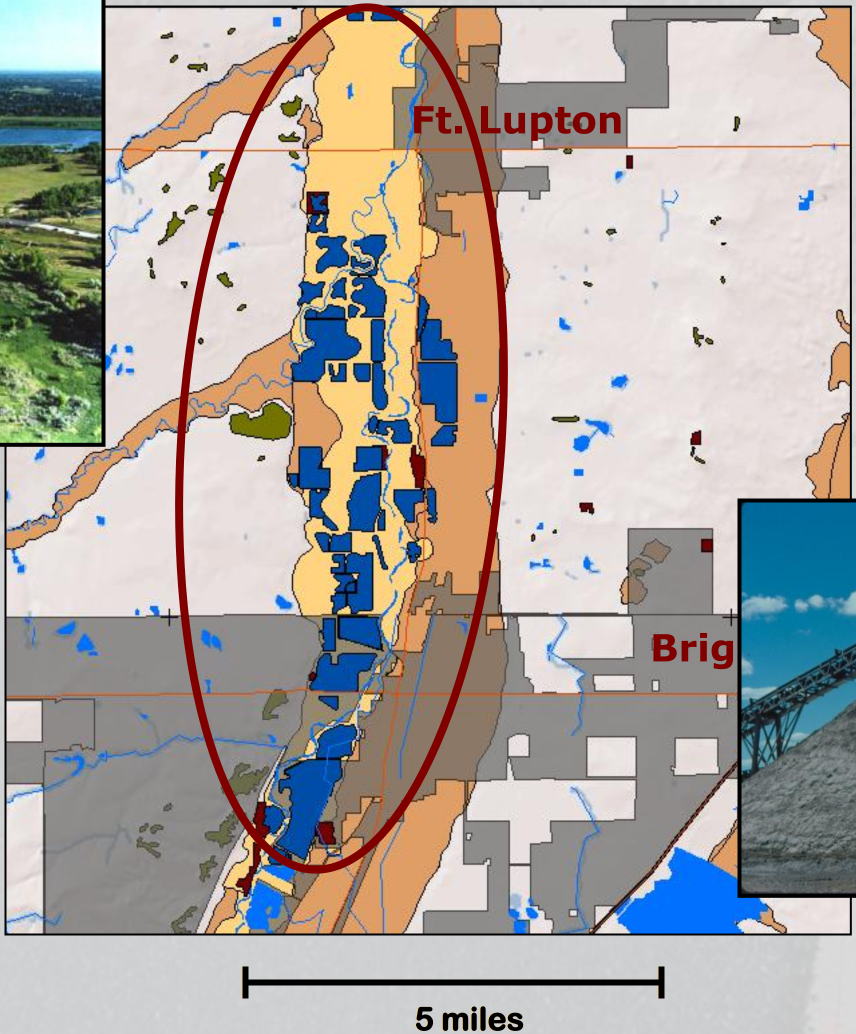
Reclaimed operations - 2010



Reclaimed operations - 2020



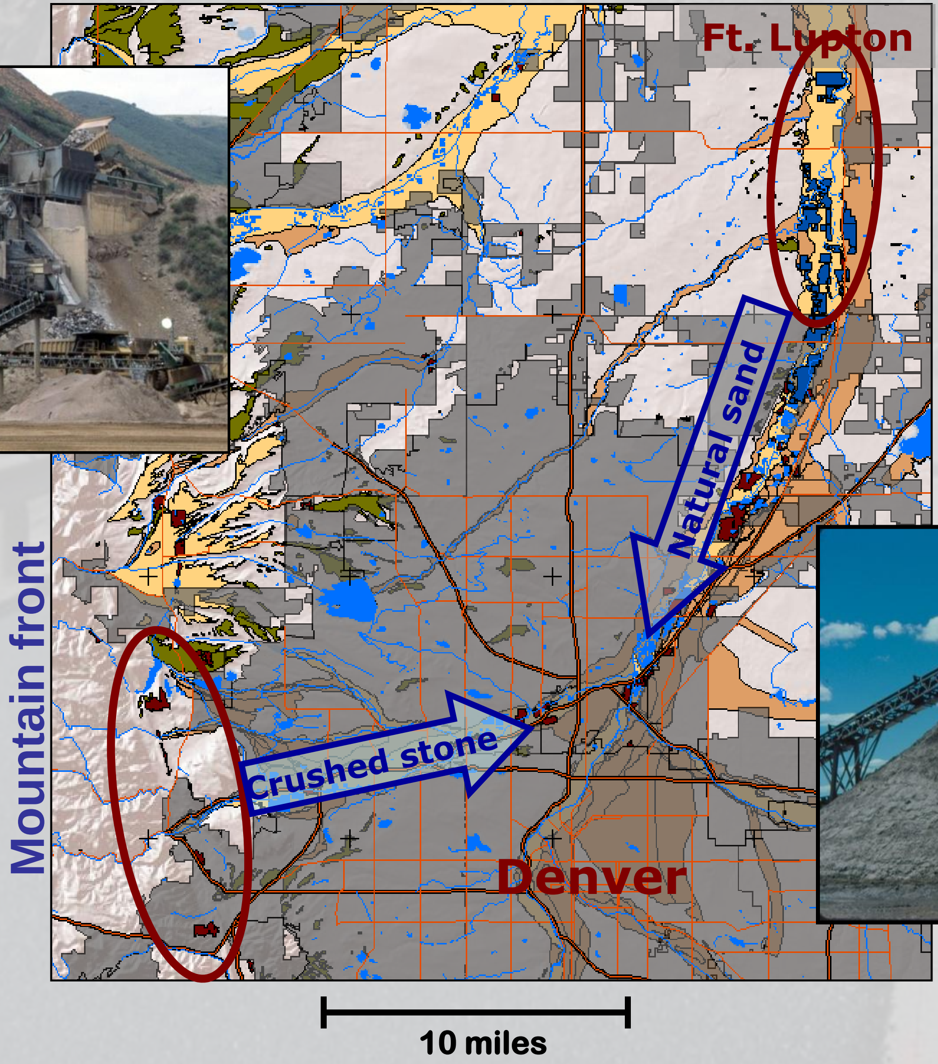
Photograph from the
Minerals Information Institute.



Photograph from Amy Lilienfield.

Blending supplies

Photograph from the U.S. Geological Survey.



Photograph from Amy Lilienfield.

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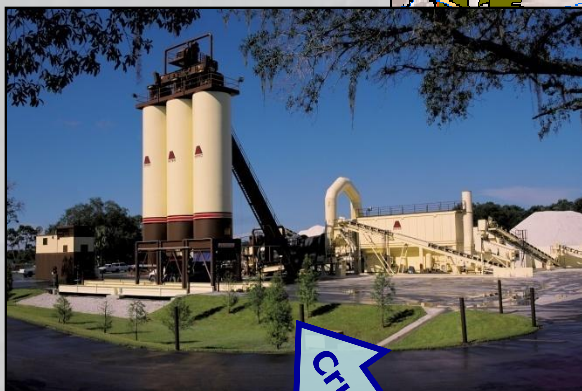
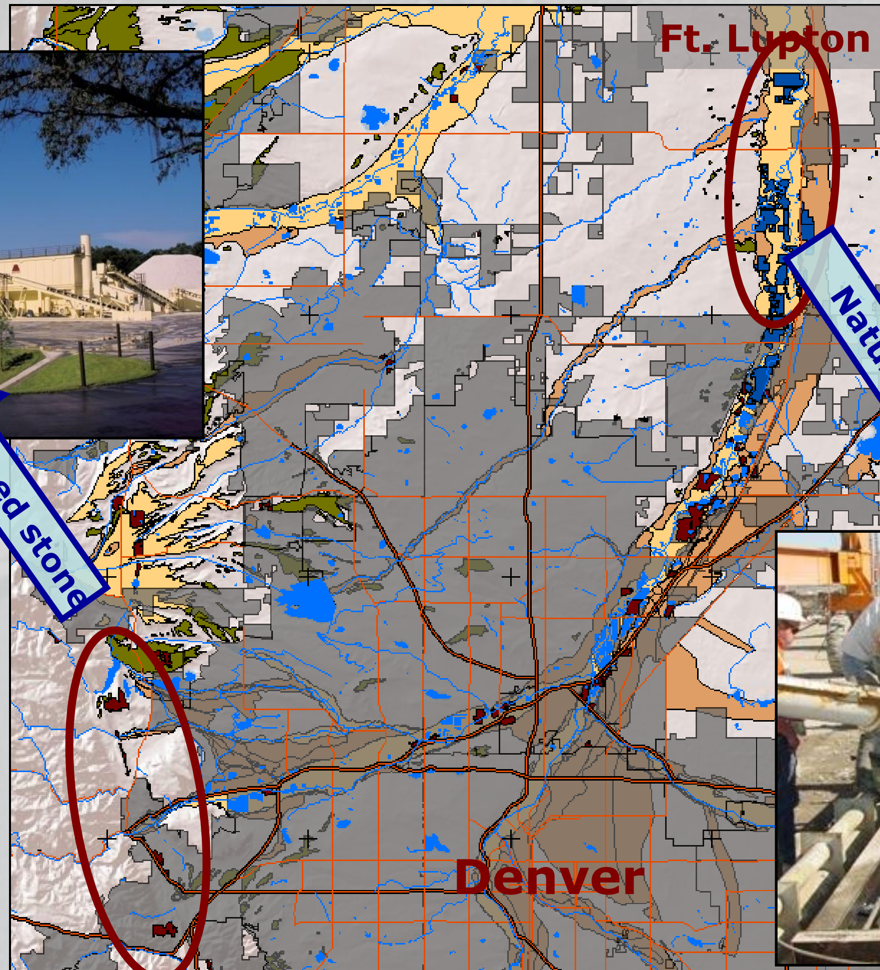
Matching supply to application



Photograph from Astec Inc.



Photograph from the Federal Highway Administration.

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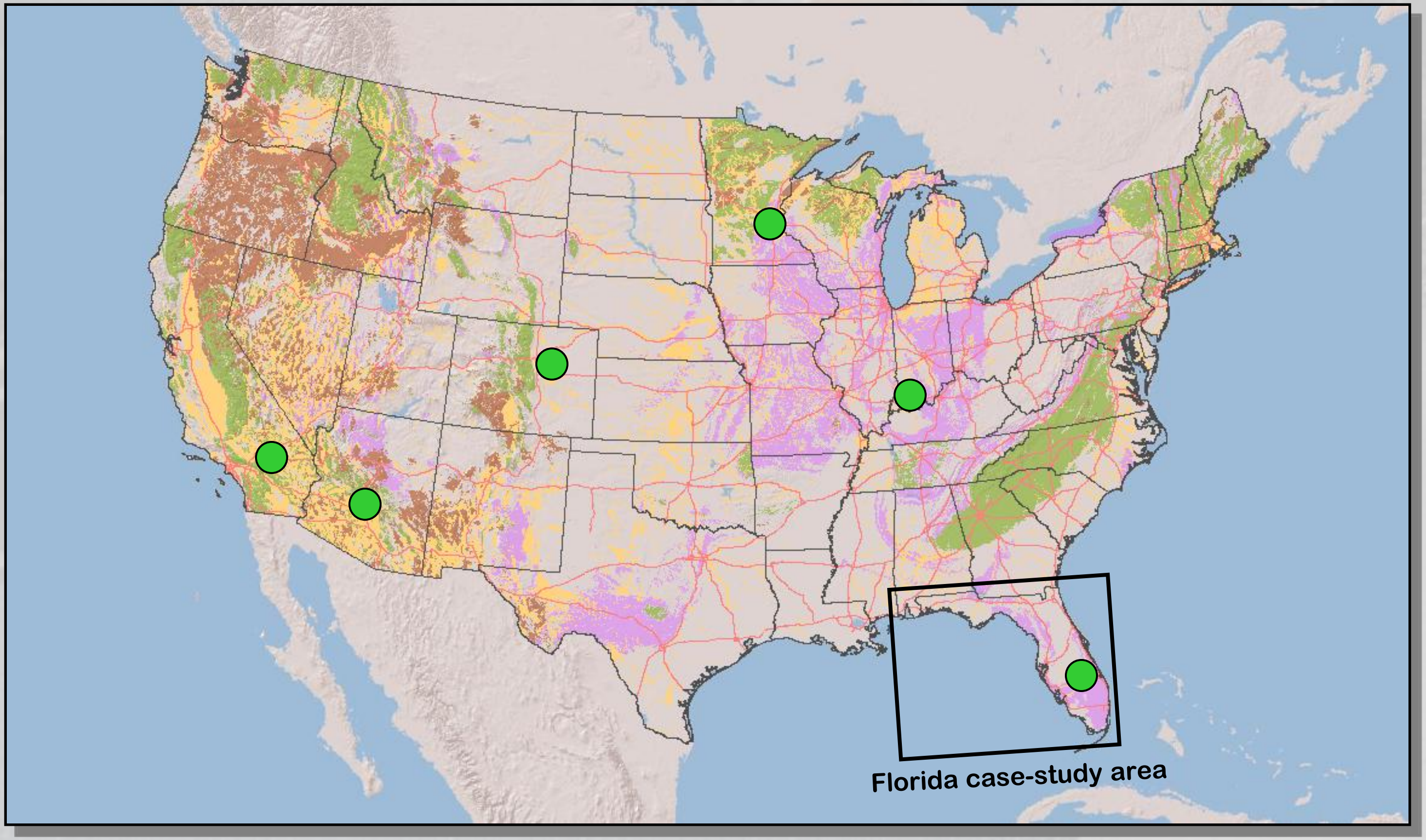
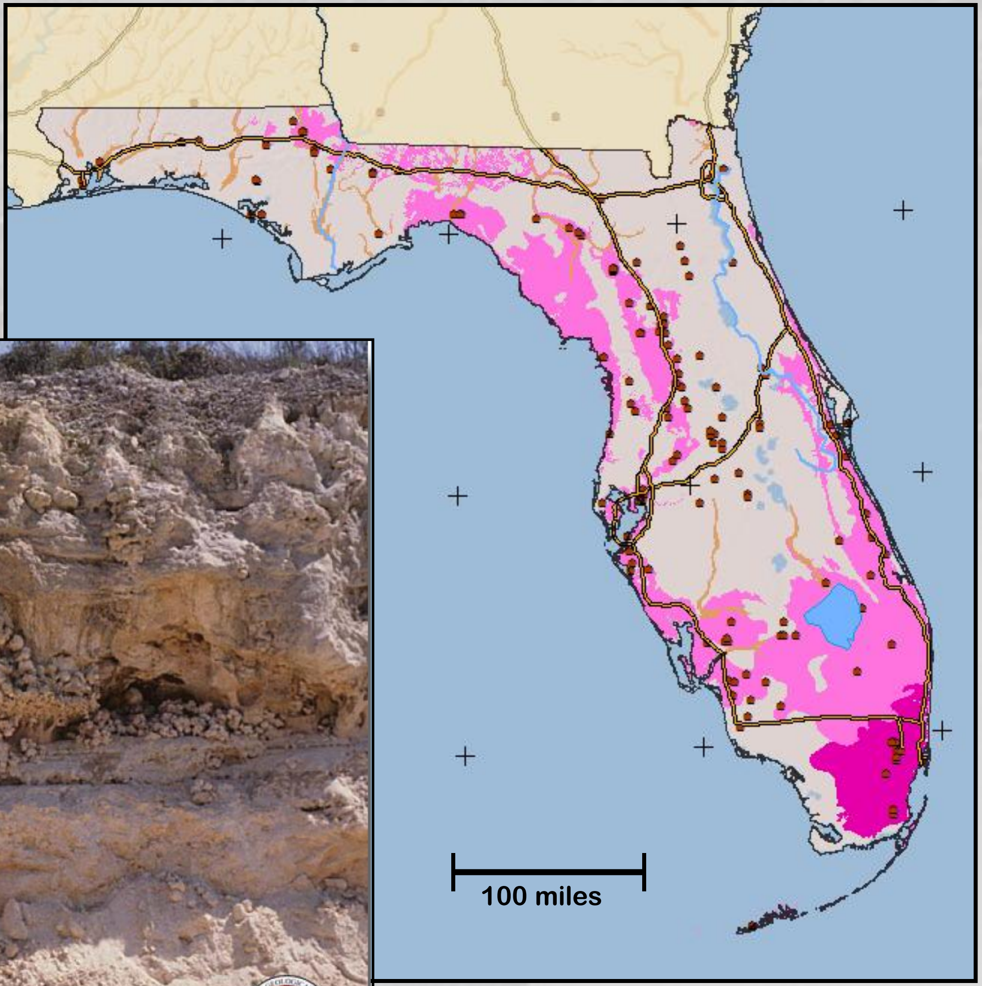
Quality Issues
Florida



Geology

Miami limestone

Other limestone



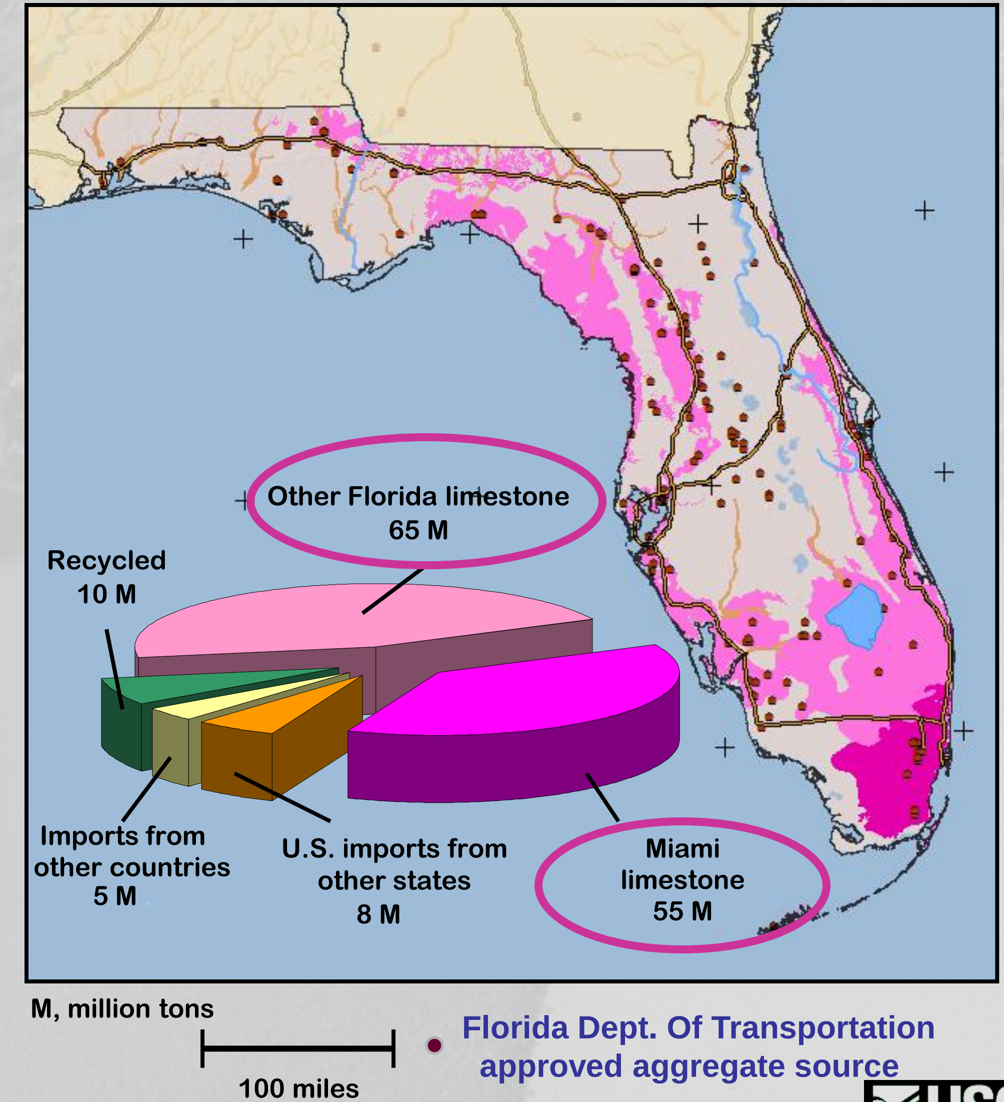
- Florida Dept. Of Transportation approved aggregate source

Photograph from the Florida Geological Survey.

Local production - 2006

Miami limestone – used as construction aggregate

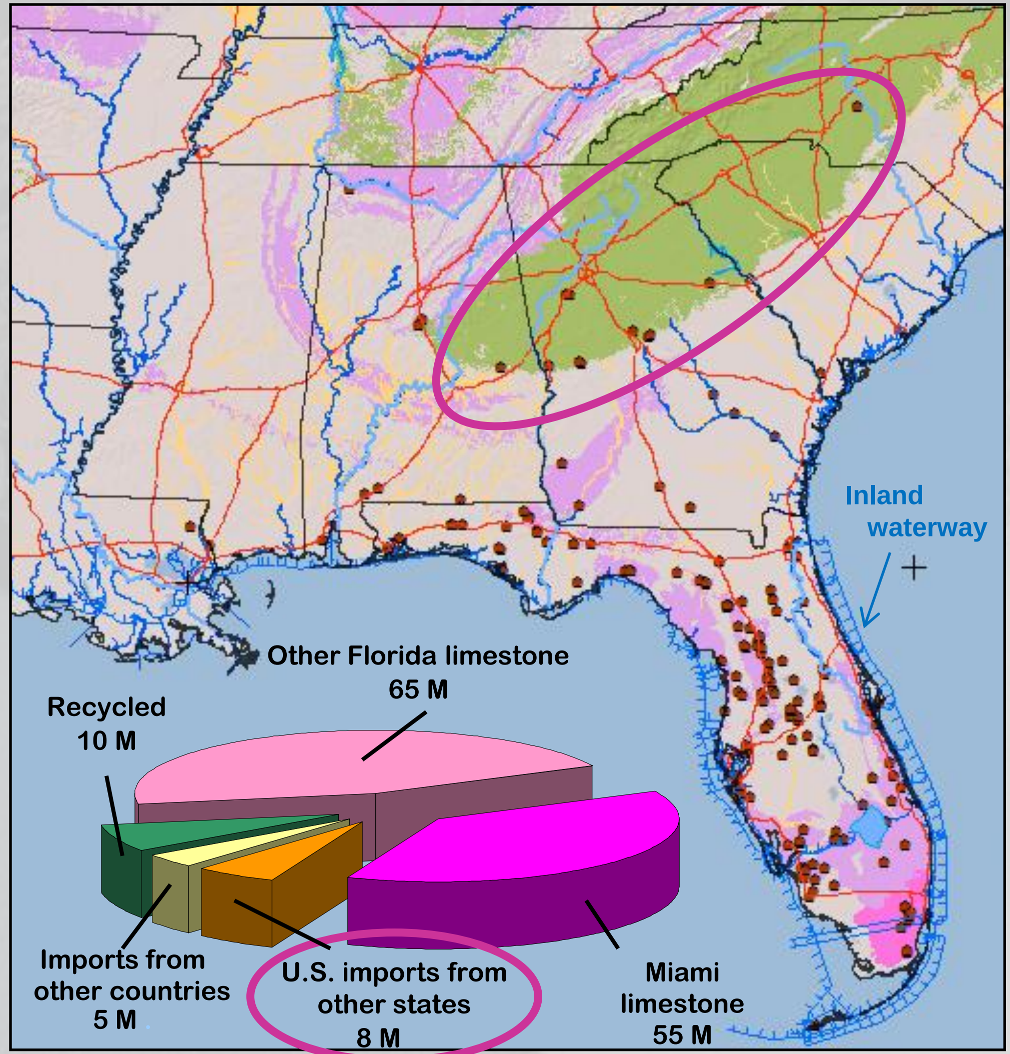
Other limestone – used as limerock (compacted durable base beneath roads and buildings) and as low-strength concrete



Imports from other states - 2006

Granite

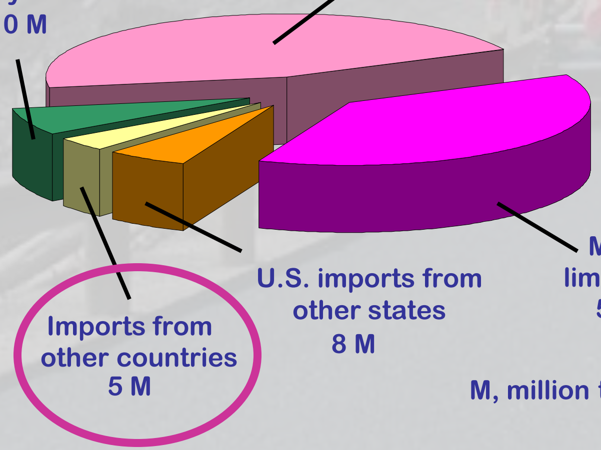
- High friction
- Abrasion resistance
- Used in SuperPave
- Used to avoid D-cracking



M, million tons

Florida Dept. Of Transportation approved aggregate source

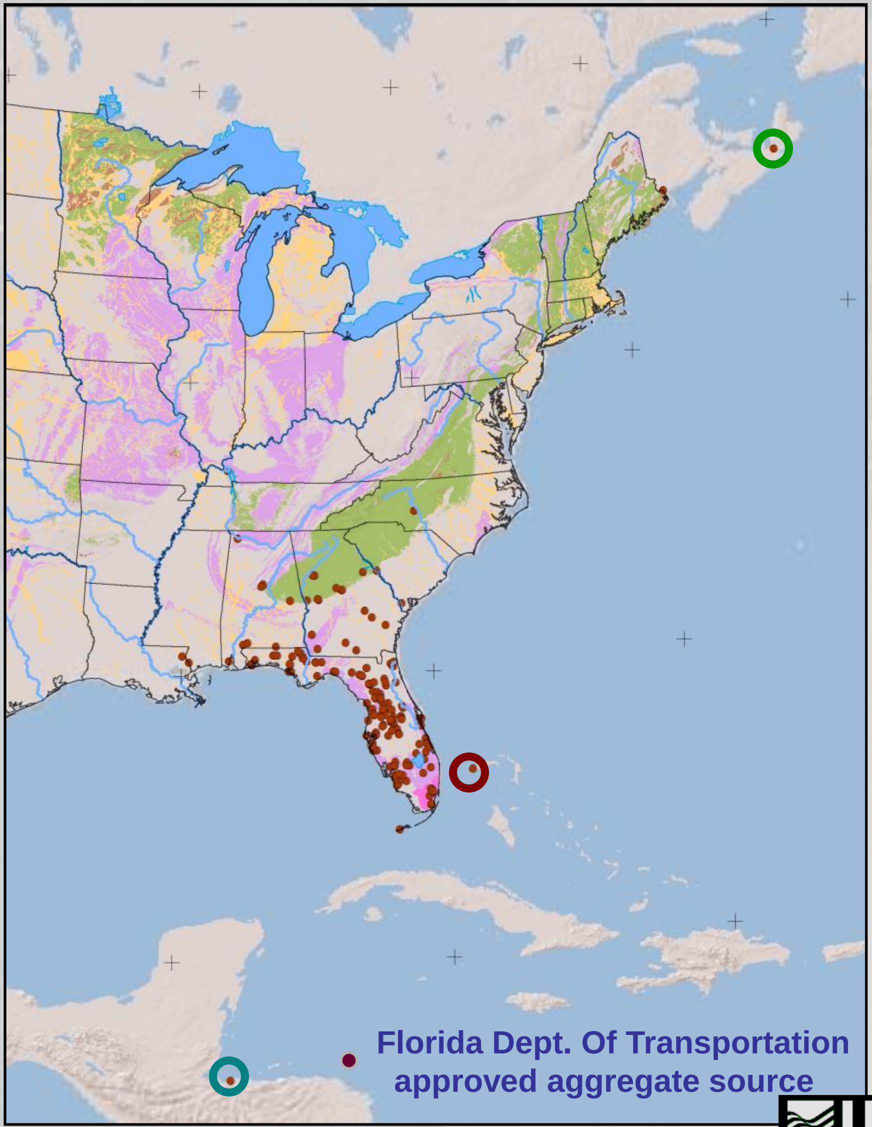
Imports from other countries - 2006



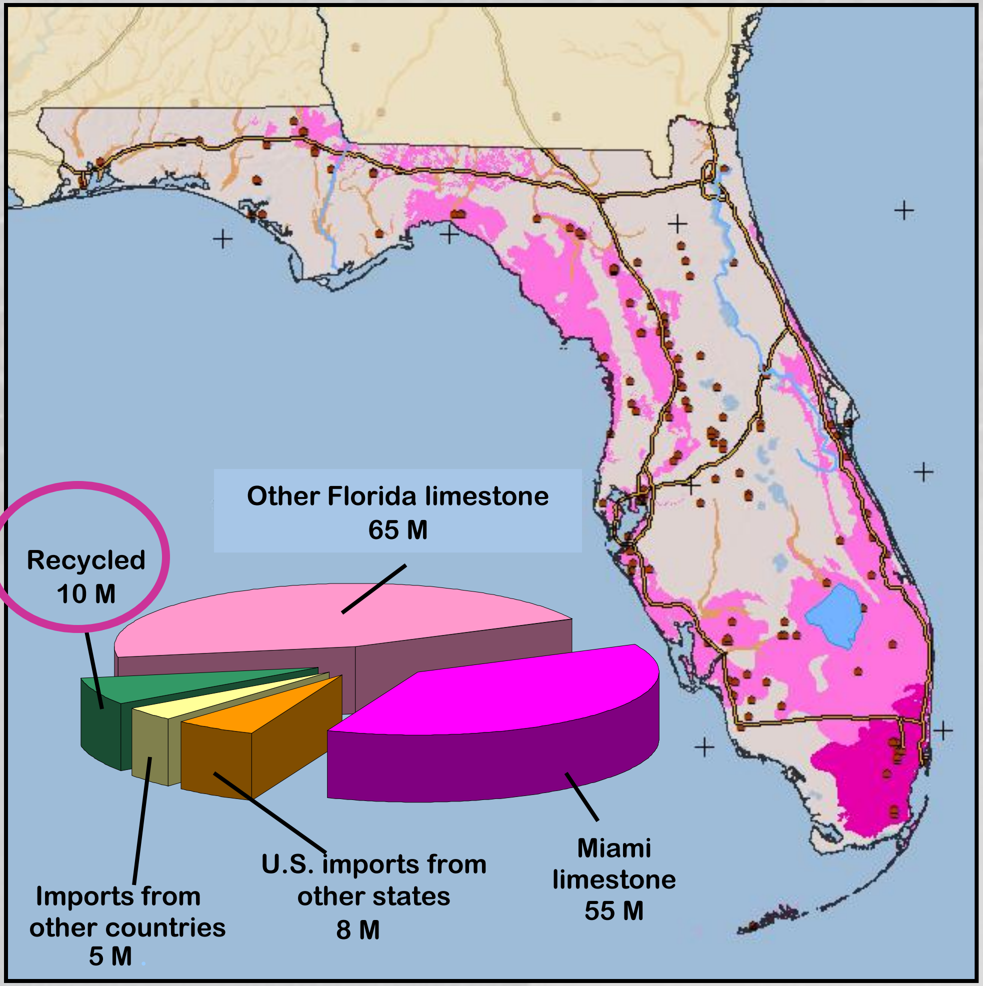
Granite from Canada

Limestone from Bahamas

Granite from Honduras



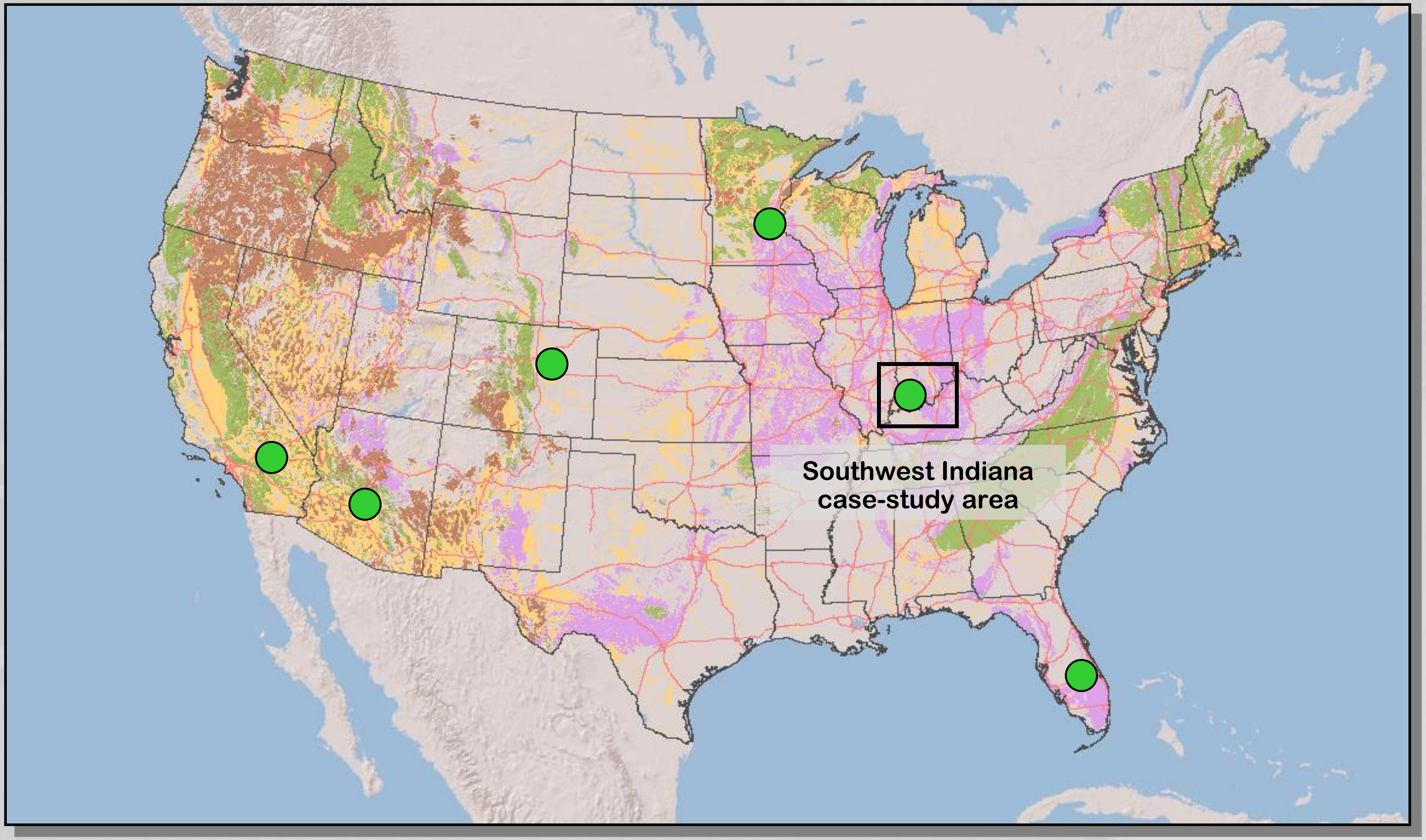
Recycled aggregate - 2006



M, million tons

Photograph from Metso Materials.

Environmental Issues
Southwest Indiana



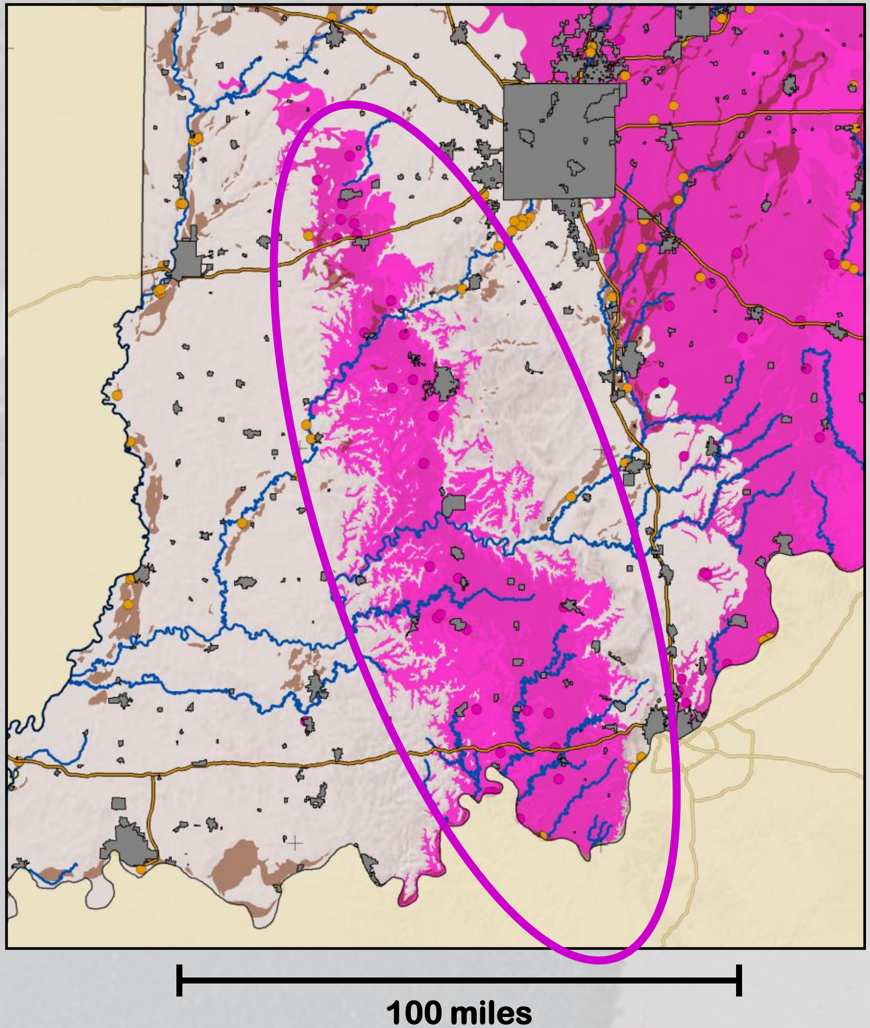
Environmental Issues

Potential sources of limestone

Potential sources of sand & gravel

Built-up areas

- **Active aggregate operations** (from Indiana Geological Survey, 2001)



Environmental issues

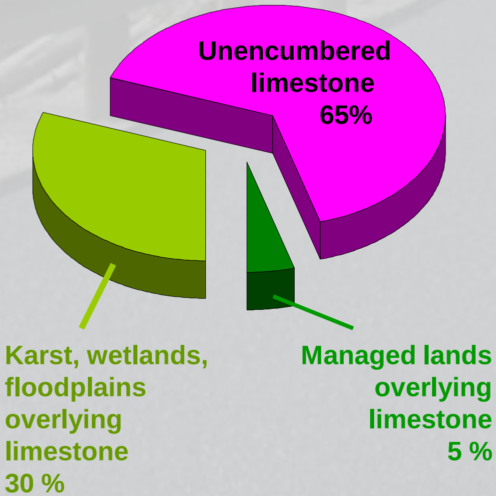
Potential sources of limestone

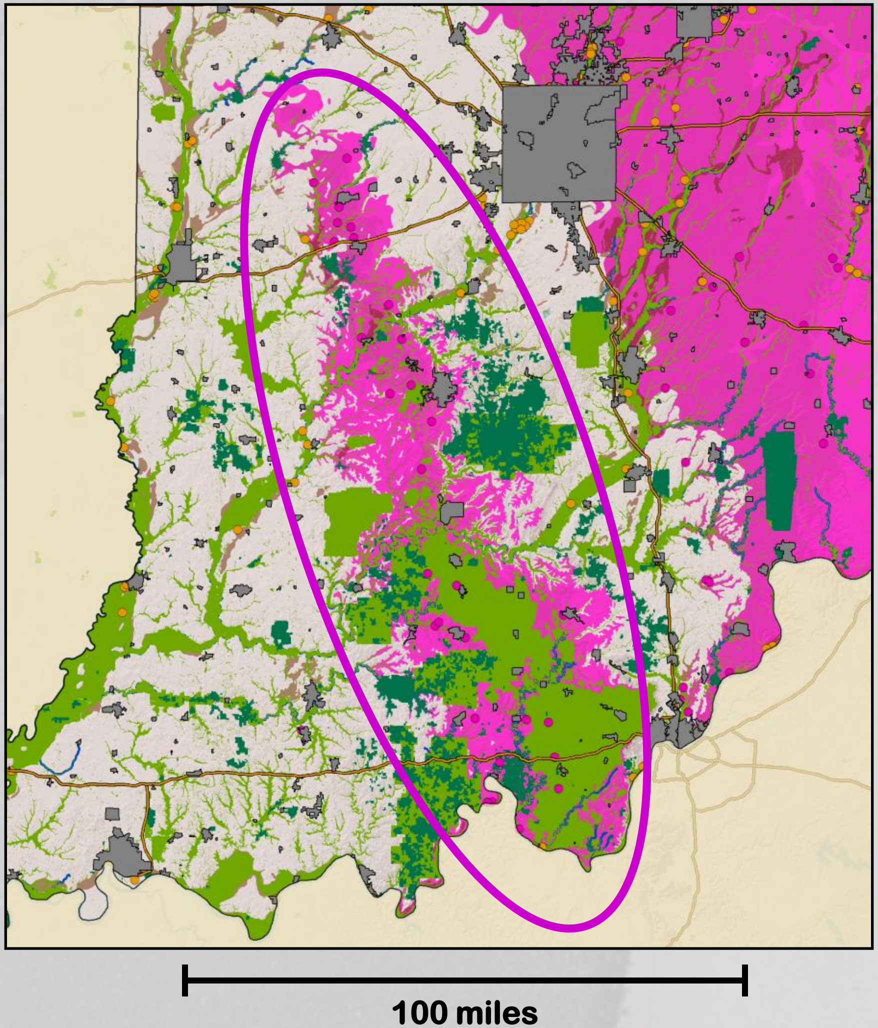
Potential sources of sand & gravel

Built-up areas

Managed lands

Karst, wetlands, floodplains





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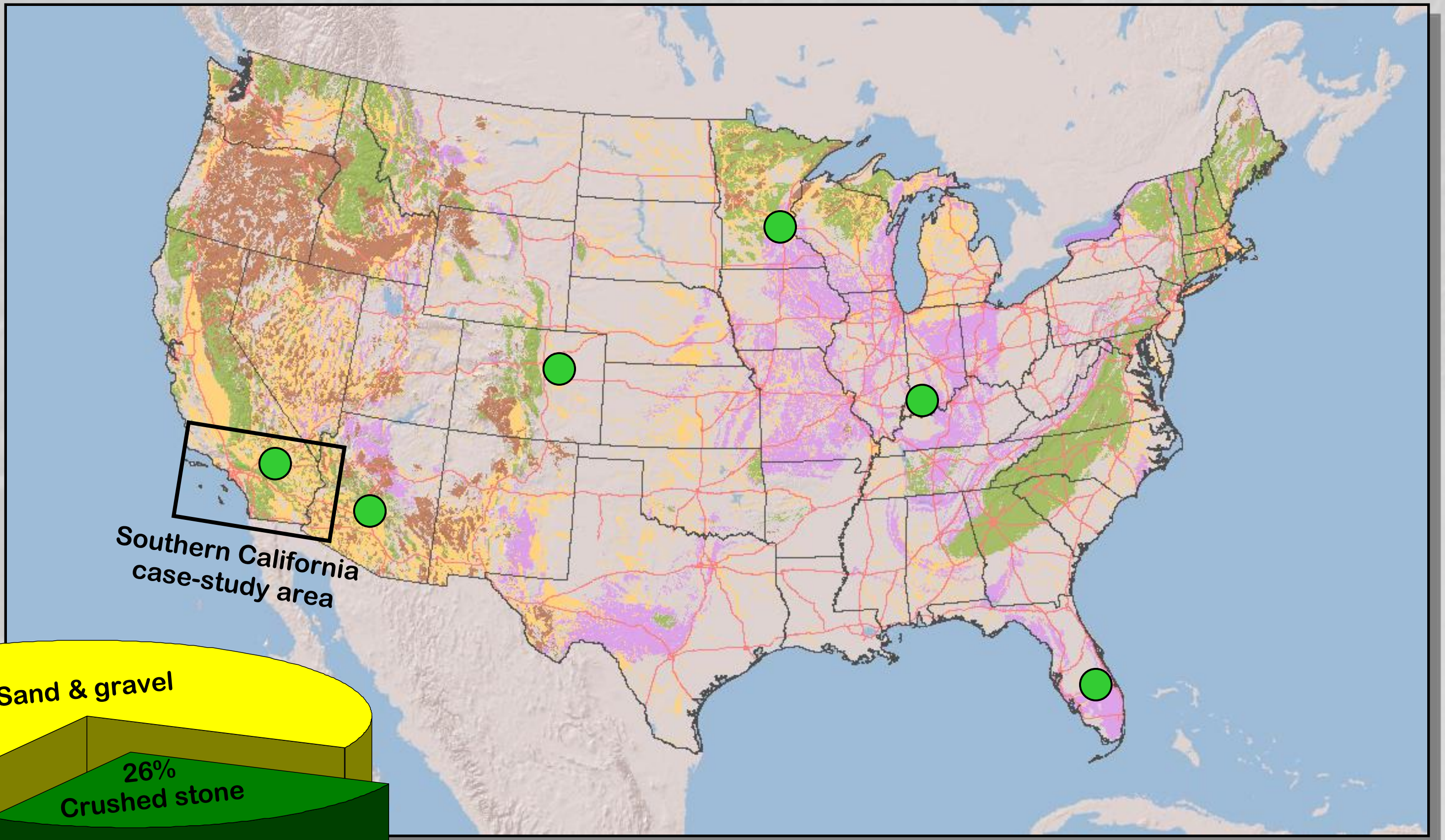
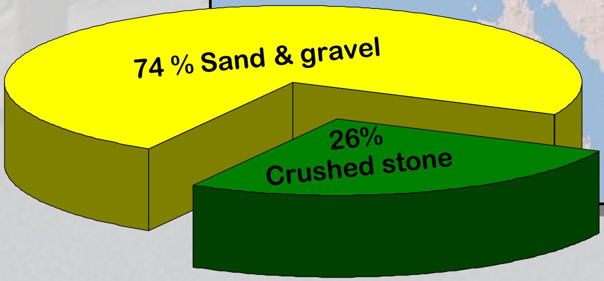
Societal Issues
Permitting – Southern California





SMARA - 1975

Surface Mining and Reclamation Act

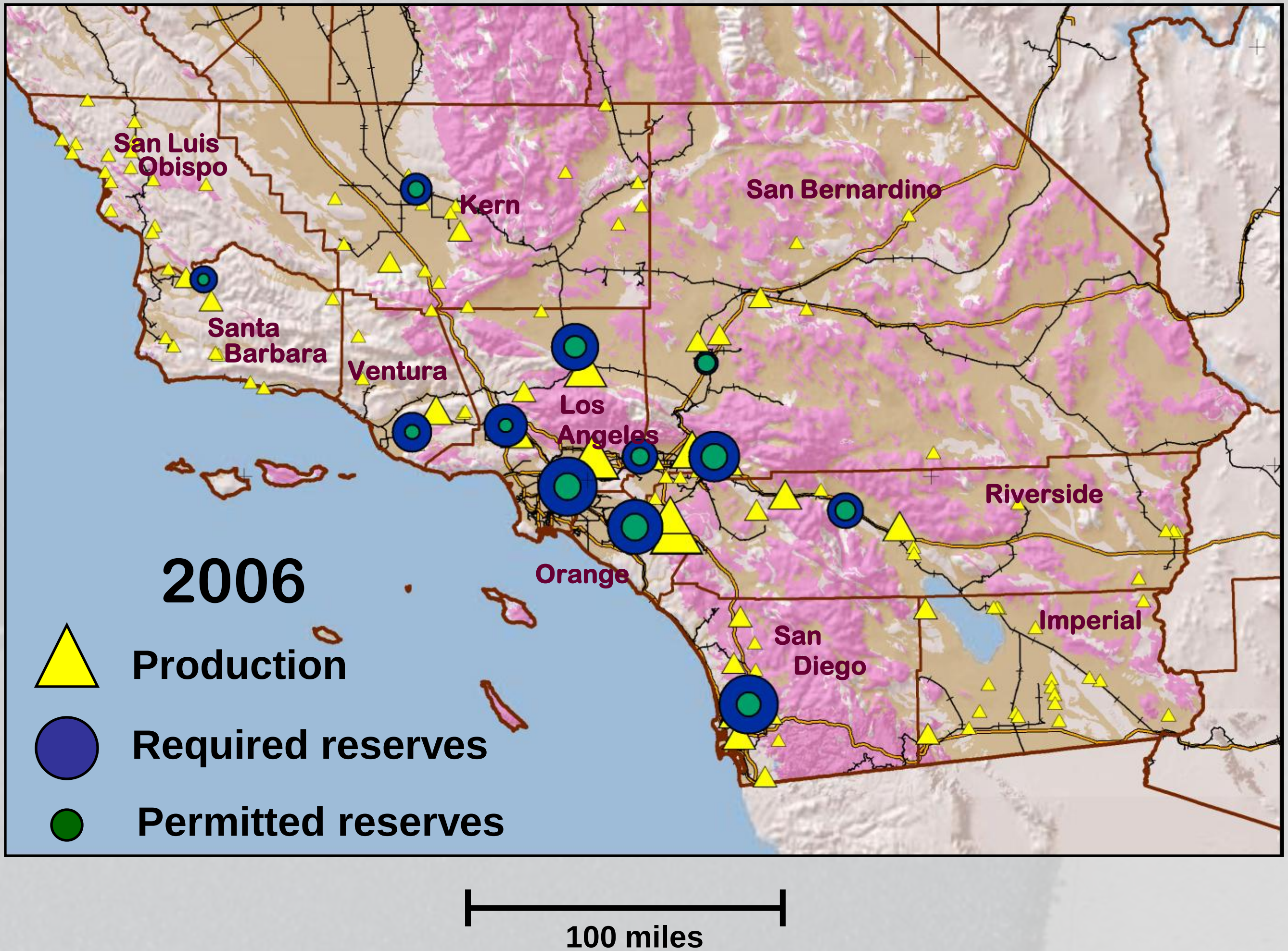
California counties are required to have **permitted aggregate resources** that meet the 50-year demand.

Permitted Aggregate Resources

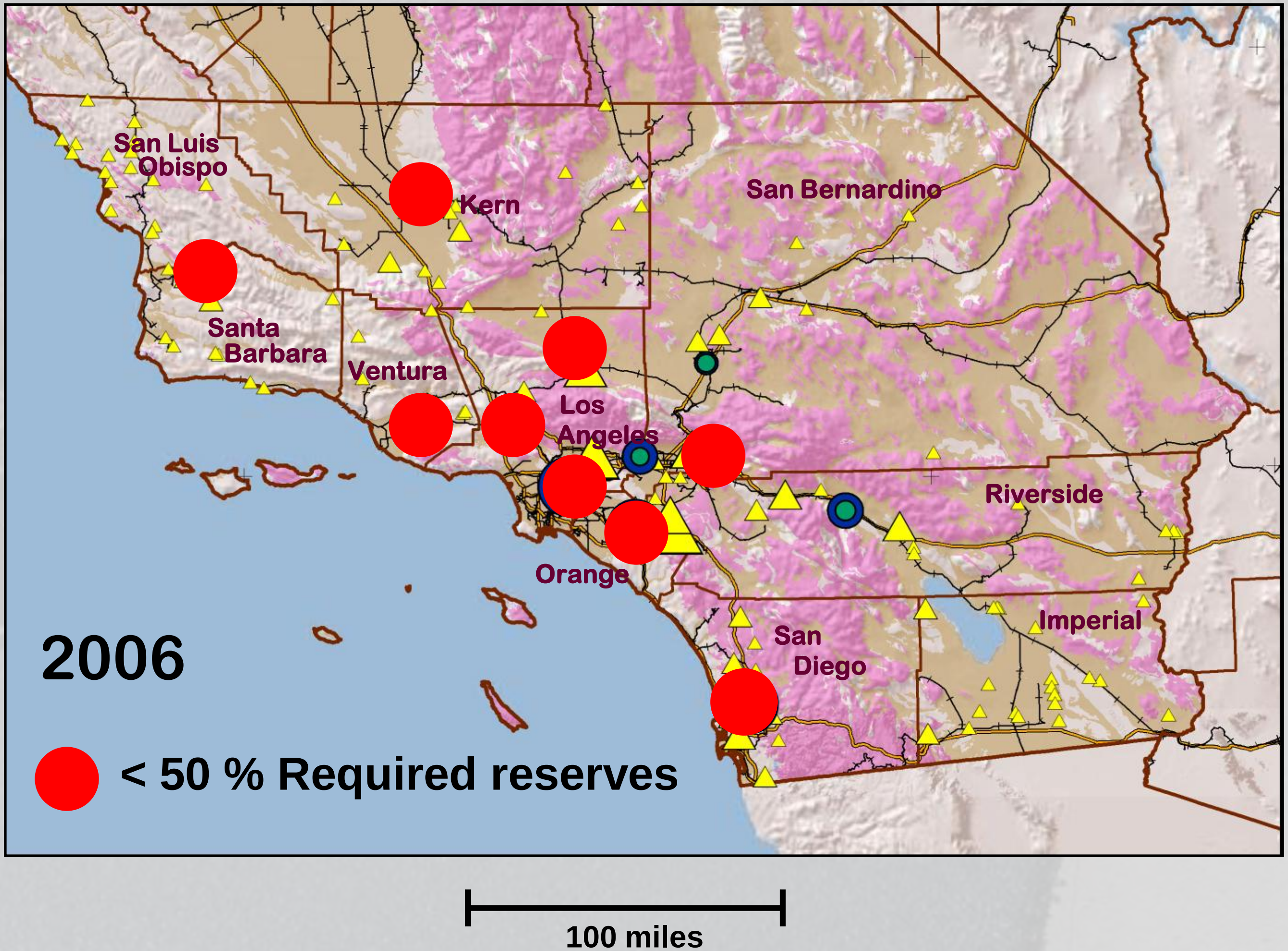
"… aggregate deposits that have been determined to be acceptable for commercial use, exist within properties owned or leased by aggregate producing companies, and **have permits allowing mining of aggregate** material."

Kohler (2006 p. 6),

Required vs Permitted Reserves Southern California



Required vs. Permitted Reserves



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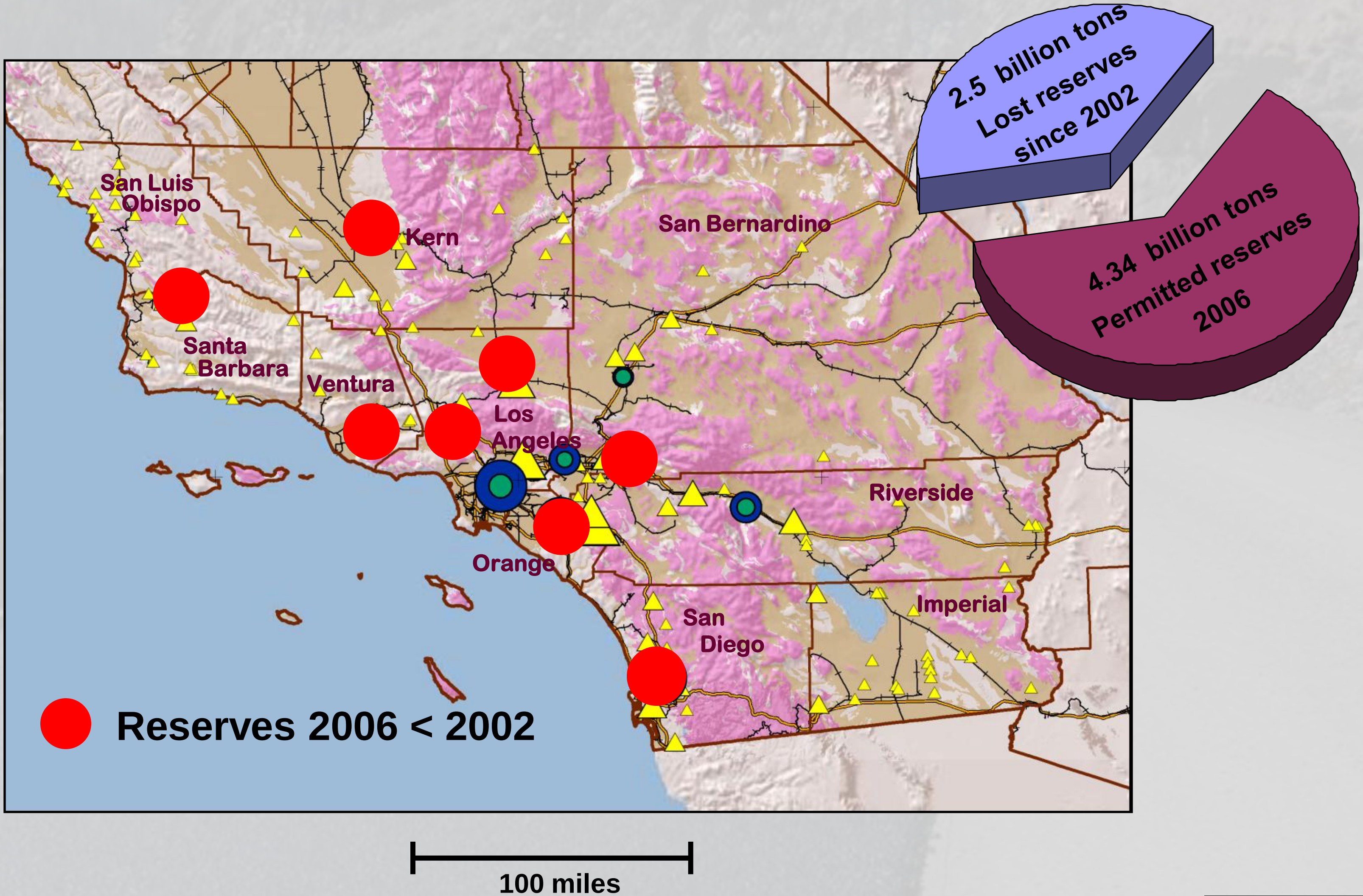
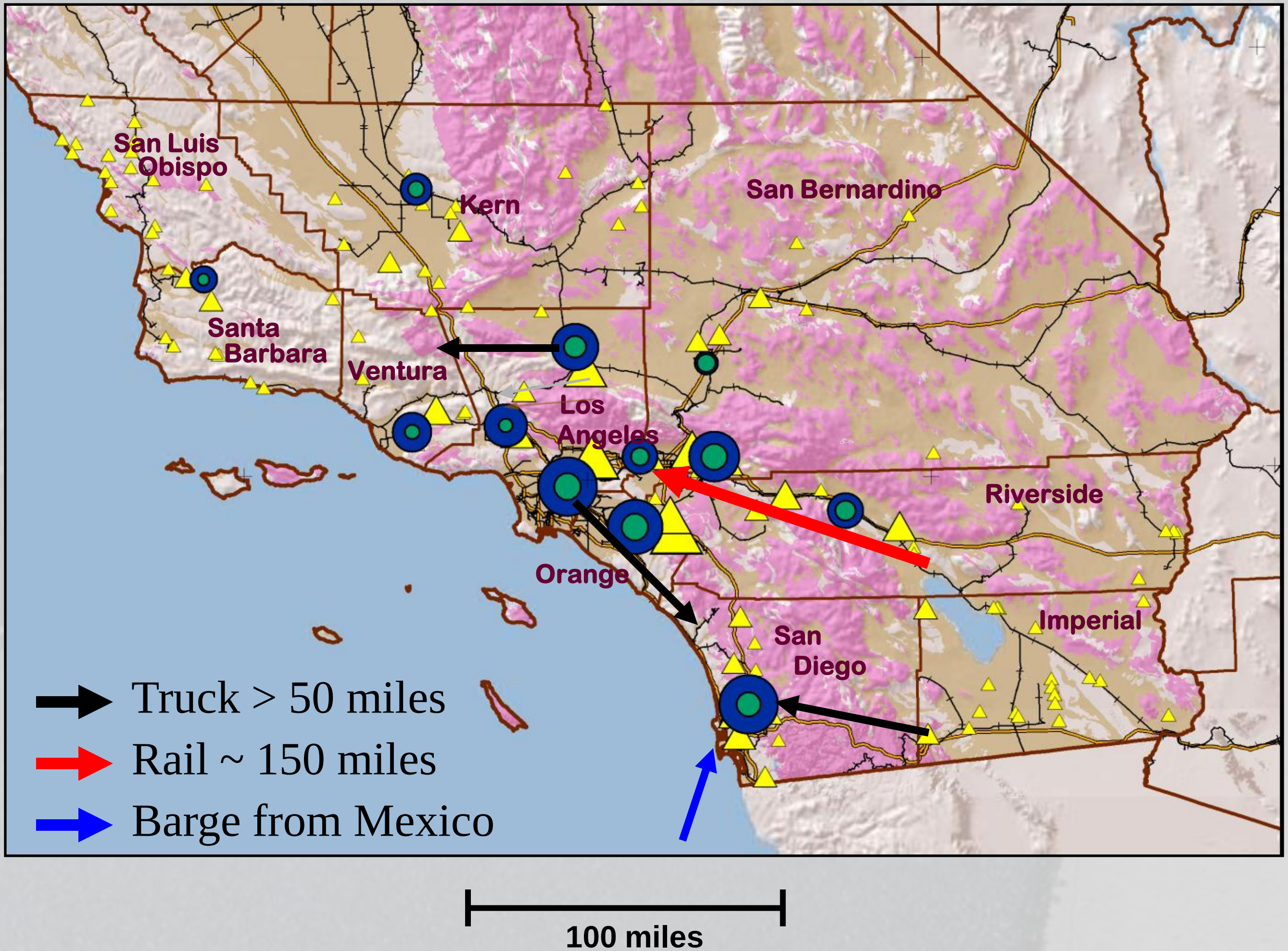
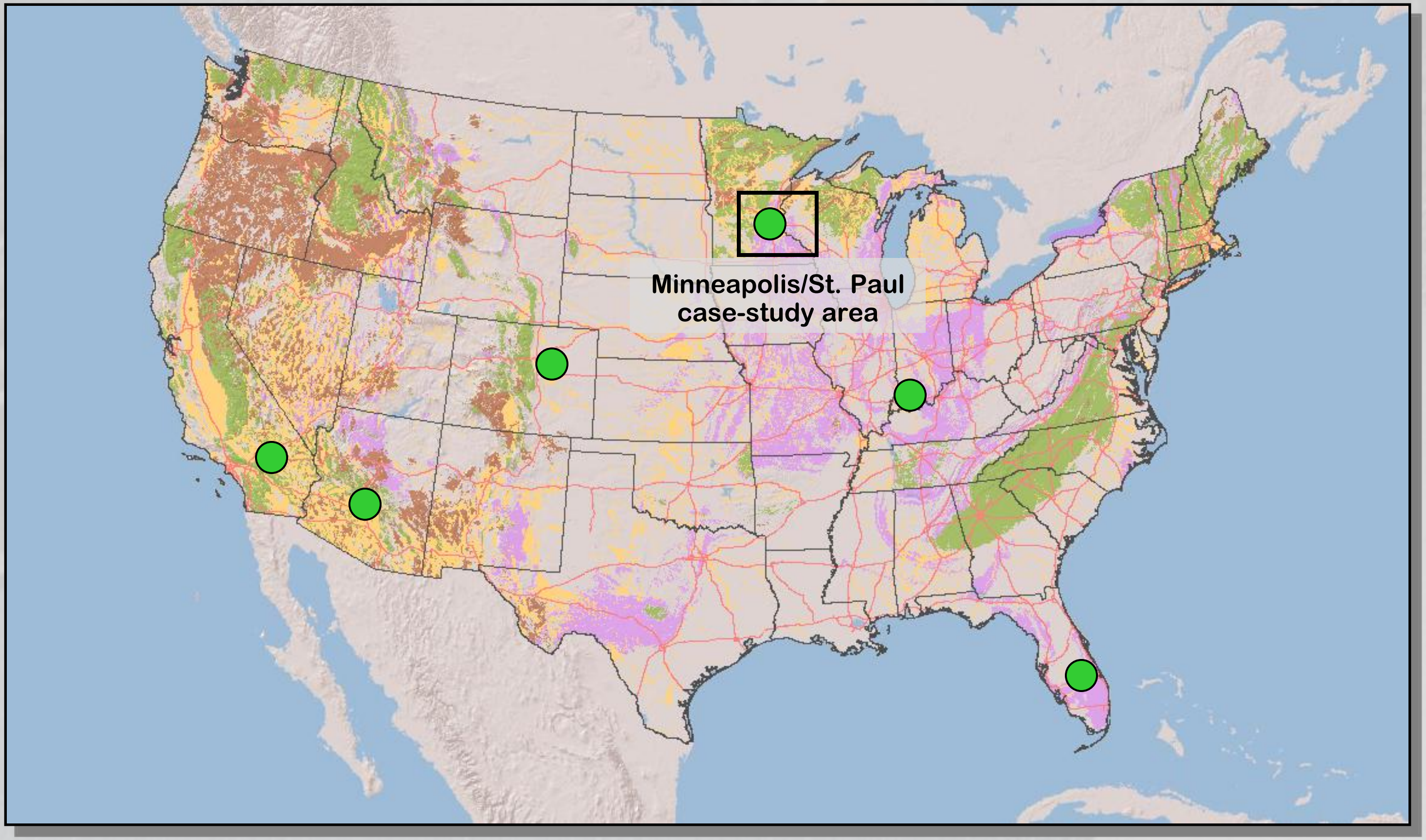
Permitted Reserves 2006 vs 2002



Transport to Overcome Shortfall



Quality Issues
Minneapolis/St. Paul, Minnesota



Quality – Alkali-Silica Reaction

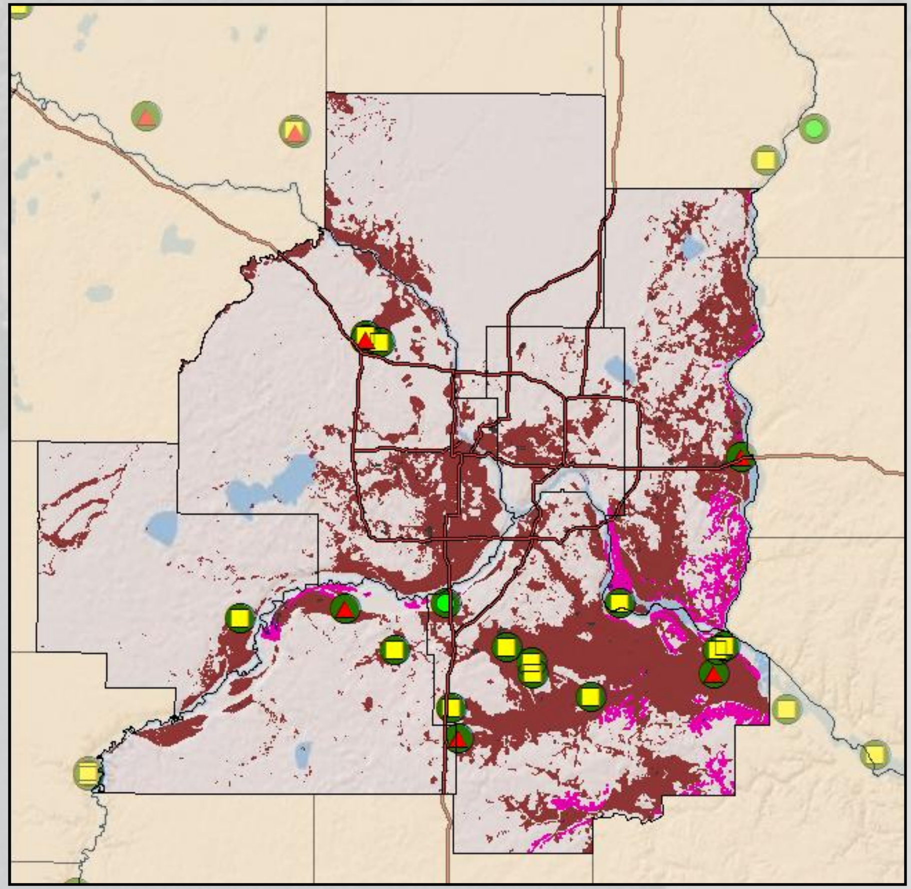
Potential sources of limestone

Potential sources of sand and gravel

Max alkali-silica reaction expansion, in percent, after 14 days

- 0-0.15
- >0.15 – 0.25
- >0.25 – 0.674

With use of fly ash



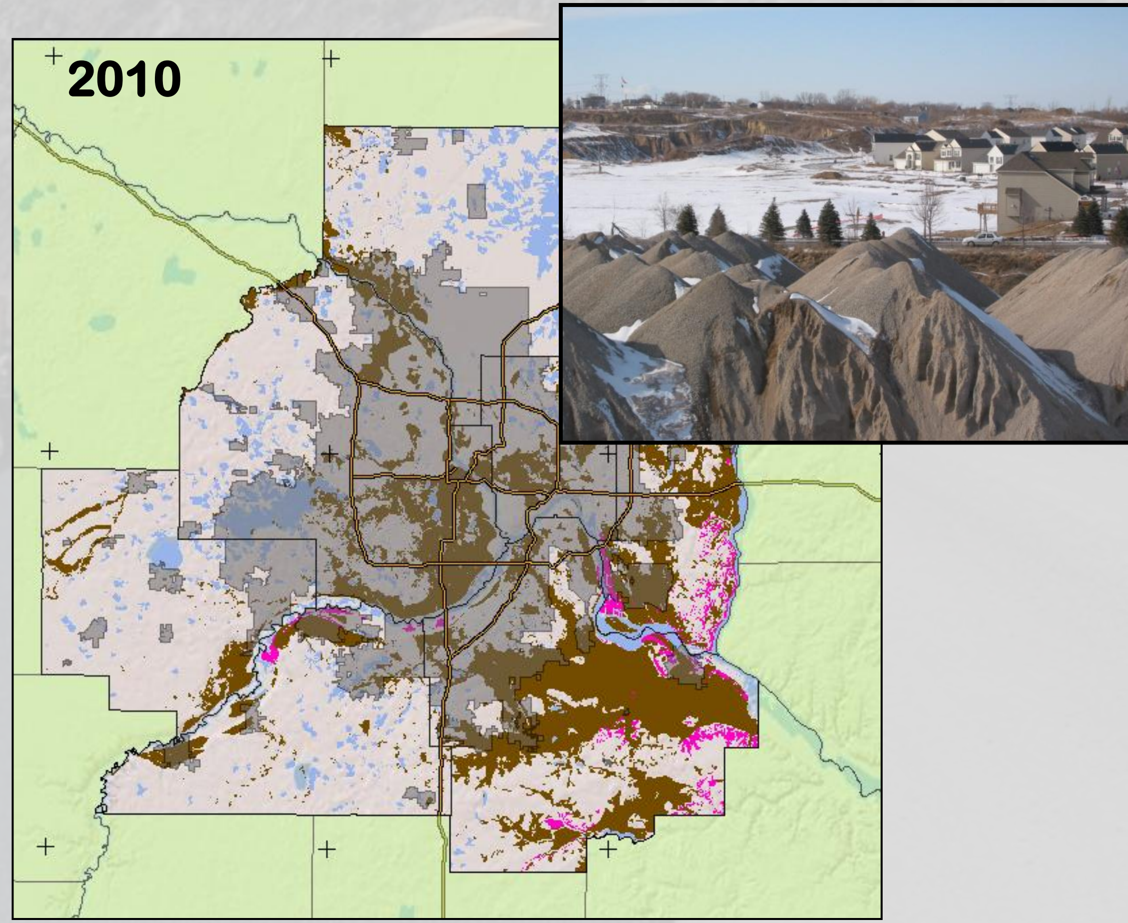
20 miles

Societal Issues – Encroachment Minneapolis/St. Paul, Minnesota

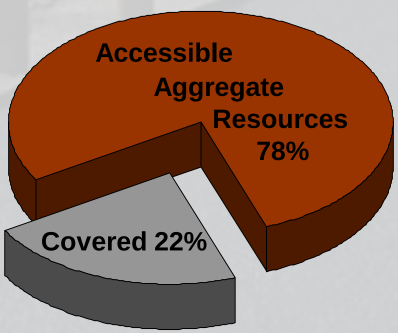
Potential sources of limestone

Potential sources of sand and gravel

Built-up areas

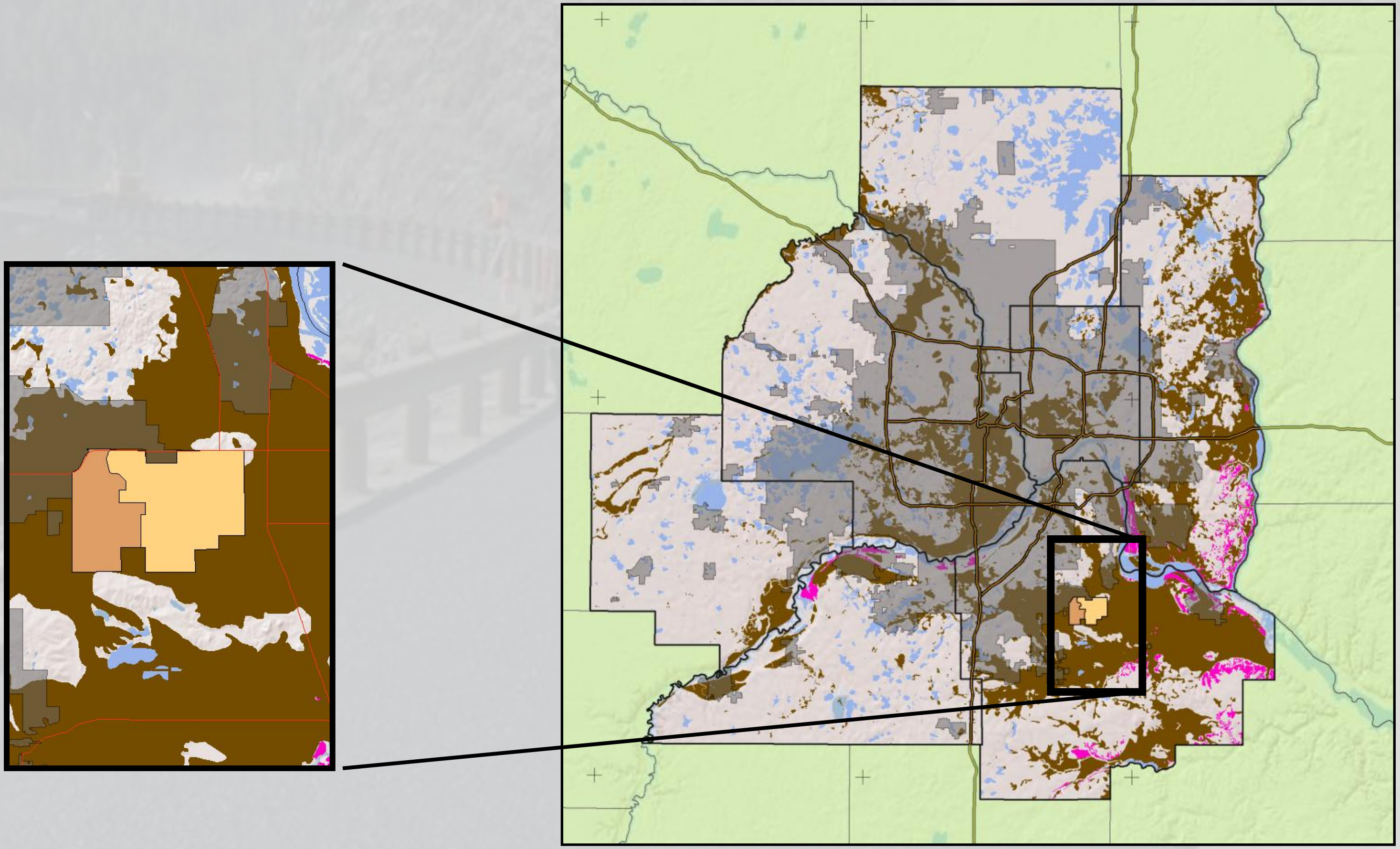


20 miles



Photograph from the U.S. Geological Survey.

Encroachment



20 miles

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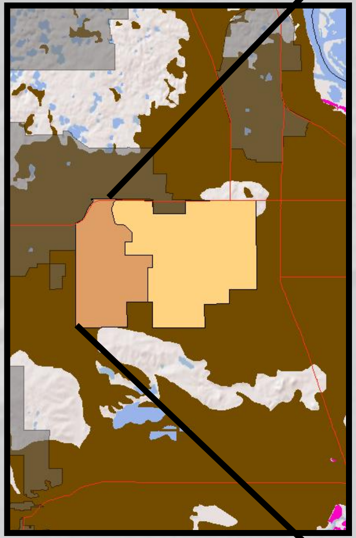
UMore Park

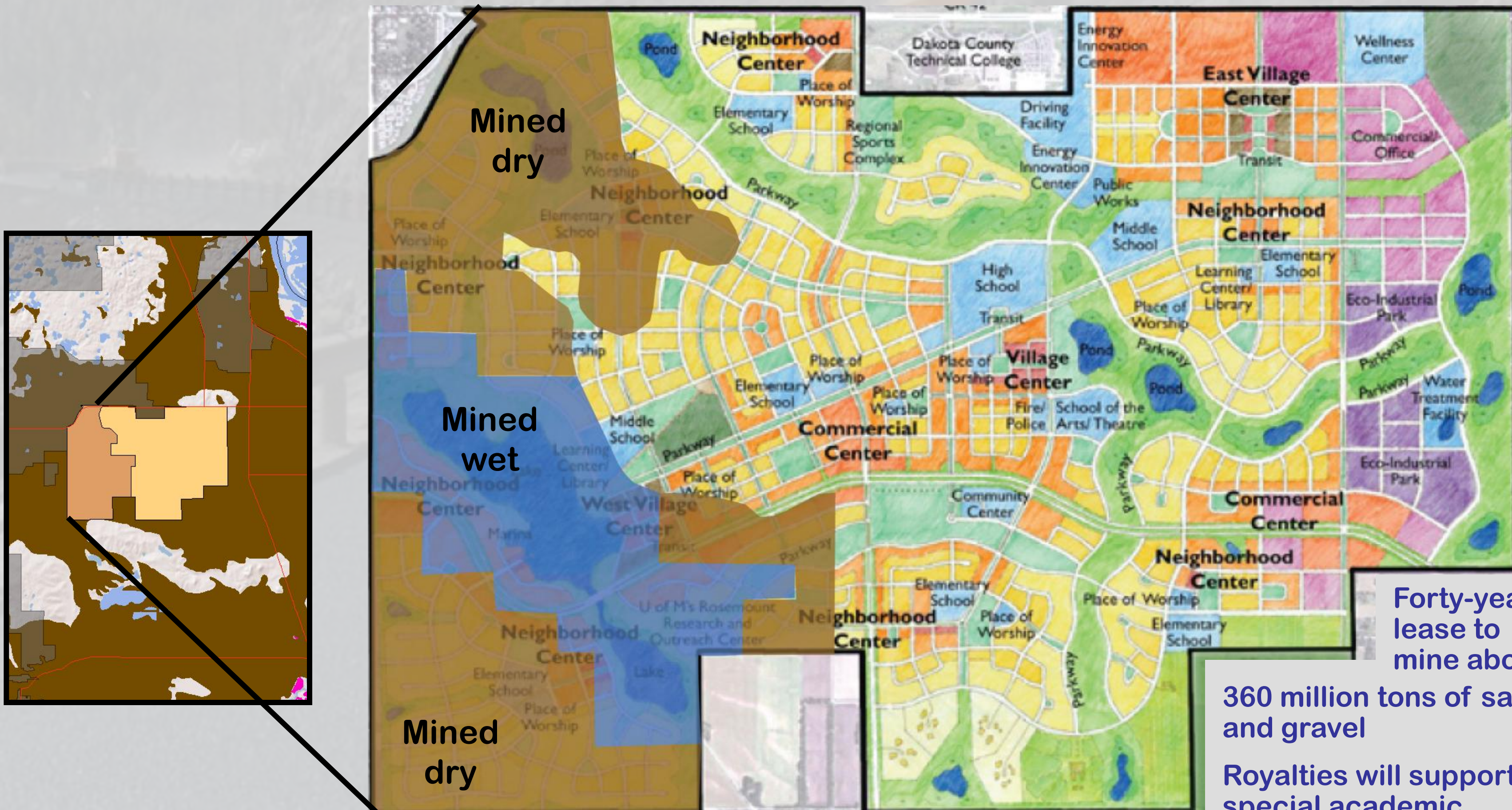
University of Minnesota Outreach, Research and Education



Vision: build a sustainable community of 20,000 to 30,000 people

UMore Park

Protecting aggregate from encroachment



Forty-year lease to mine about 360 million tons of sand and gravel

Royalties will support special academic pursuits.

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Summary
Issues

- A large supply of aggregate will be needed to repair the Nation’s transportation infrastructure.
- Aggregate is widespread but does not occur everywhere.
- Aggregate may not meet quality requirements for specific uses.
- Aggregate development may be prohibited by encroachment.

Summary
Solutions (from case studies)

- Geologic knowledge of deposits can help understand:
  - Occurrence or absence of potential aggregate resources
  - Characteristics of aggregate resources.

- Project design can include:
  - Use of local marginal material (anhydrite, cinders) for appropriate applications such as base course and high quality material for applications such as wearing surfaces
  - Use of local unconventional material such as clinker or cinder (as light-weight aggregate) in high-specification uses
  - Use of high-specification material imported from outside the state
  - Use of aggregates blended from different source areas
  - Use of recycled aggregate.

- Efficient transport (back-haul and multi-modal transport) can help minimize costs of aggregate transport.

- Including the consideration of aggregate resources in plans of growth and development can help protect local aggregate supplies.

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Aggregate Resource Availability in the Conterminous United States

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