CURRENT MINING OF OLIVINE AND SERPENTINE

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Mg-rich ultramafic occurrences in the United States

- Includes dunite, perioditite, and serpentinite
  - Dunite and perioditite may be mined for olivine
    - Olivine is produced only in North Carolina and Washington
  - Serpentinite may be mined for asbestos content
    - Only one asbestos mine in the United States, in California
  - Serpentinite also may be mined and used as crushed stone, mainly for roadbed aggregate

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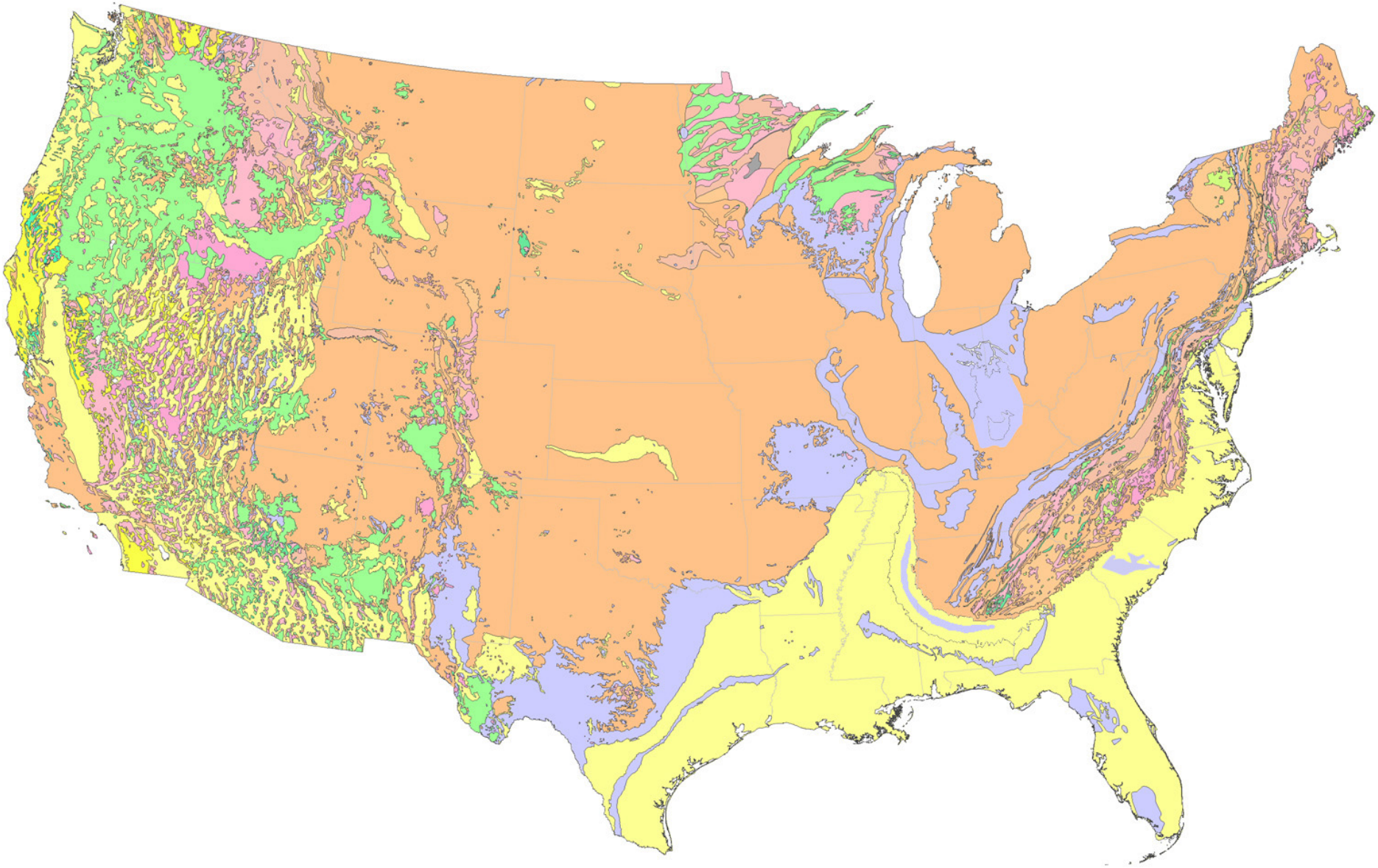

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Properties of olivine $(Mg,Fe)_2SiO_4$

- Solid solution of forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4); substitution of Fe^{2+} with Mg^{2+} in crystal structure
- Water-free and basic
- High melting point (1,760º C)
- High magnesium content
- Excellent heat storage properties
- High relative density (3.3 g/cm^3)
- Stable chemical composition
- Hard-grained (Moh's hardness 6.5-7.0)

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Specifications of commercial olivine

MgO	45%–51%
SiO_2	40%–43%
Fe_2O_3	7%–8%
CaO	0.2%–0.8%
$Al_2O_3 + TiO_2$	1.8%–2%

Price range: $50-$110 per short ton, depending on grade and size

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U.S. olivine at a glance

- U.S. production is less than 100,000 metric tons annually
- Imports, almost exclusively from Norway, average between 150,000 and 200,000 metric tons annually (2000—201,000 metric tons)
  - More than half goes to Bethlehem Steel, most likely for use as a slag conditioner
- Exports, mainly to South America, are less than 1,000 metric tons annually
- Consumption is estimated to be between 225,000 and 250,000 tons annually

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Uses of olivine

- Slag conditioning
- Foundry sand
- Refractories
- Abrasives
- Soil conditioning
- Heat storage

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Uses of domestically produced olivine in 2000

- Foundry uses—87%
- Refractory applications—7%
- Sandblasting and other abrasive uses—6%

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U.S. producers of olivine

- Unimin Corp.
  - Mines in North Carolina and Washington
  - Processing plants in Indiana, North Carolina, and Washington
- Olivine Corp.
  - Mine and plant in Washington

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Unimin Corp.

- North Carolina
  - Reserves in the Smokey Mountains total about 200 million metric tons
  - Material is sorted to remove unaltered material
- Washington
  - Reserves in the Cascade Mountains total about 1,700 million metric tons
  - Processes crude olivine produced by Olivine Corp.
- Indiana
  - Processes olivine imported from Norway into foundry and aggregate grades

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Olivine Corp.

- Mostly produces refractory-grade material, but produces small quantity of foundry-grade material

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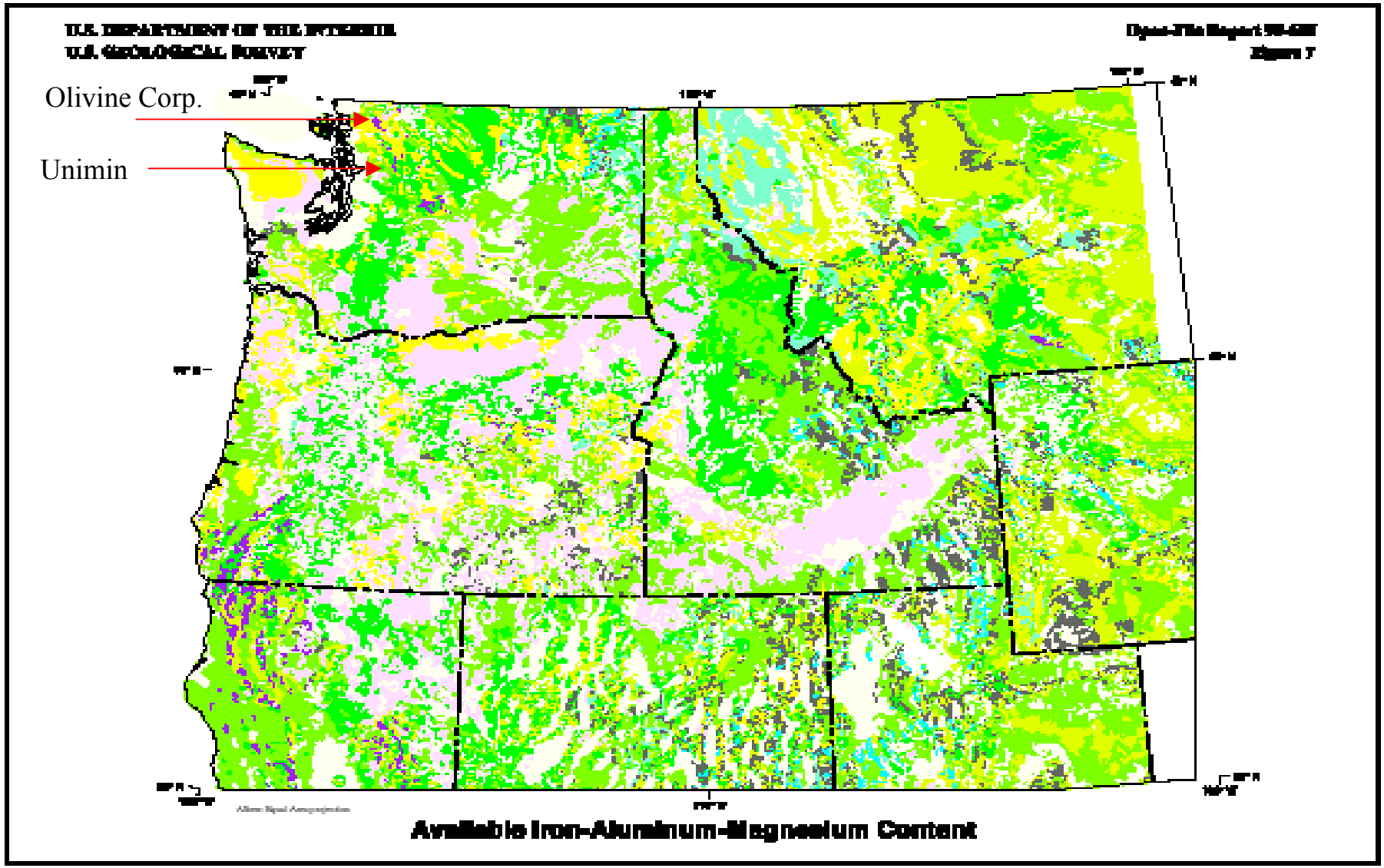

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Olivine production, by country, (Thousand metric tons) (e)

	1995	1999
Norway	5,850	6,300
Japan	900	900
Spain	500	500
United States	90	90
Italy	50	50
Others	40	65
Total	7,430	7,945
Note: (e) estimate		
Source: Industrial Minerals		

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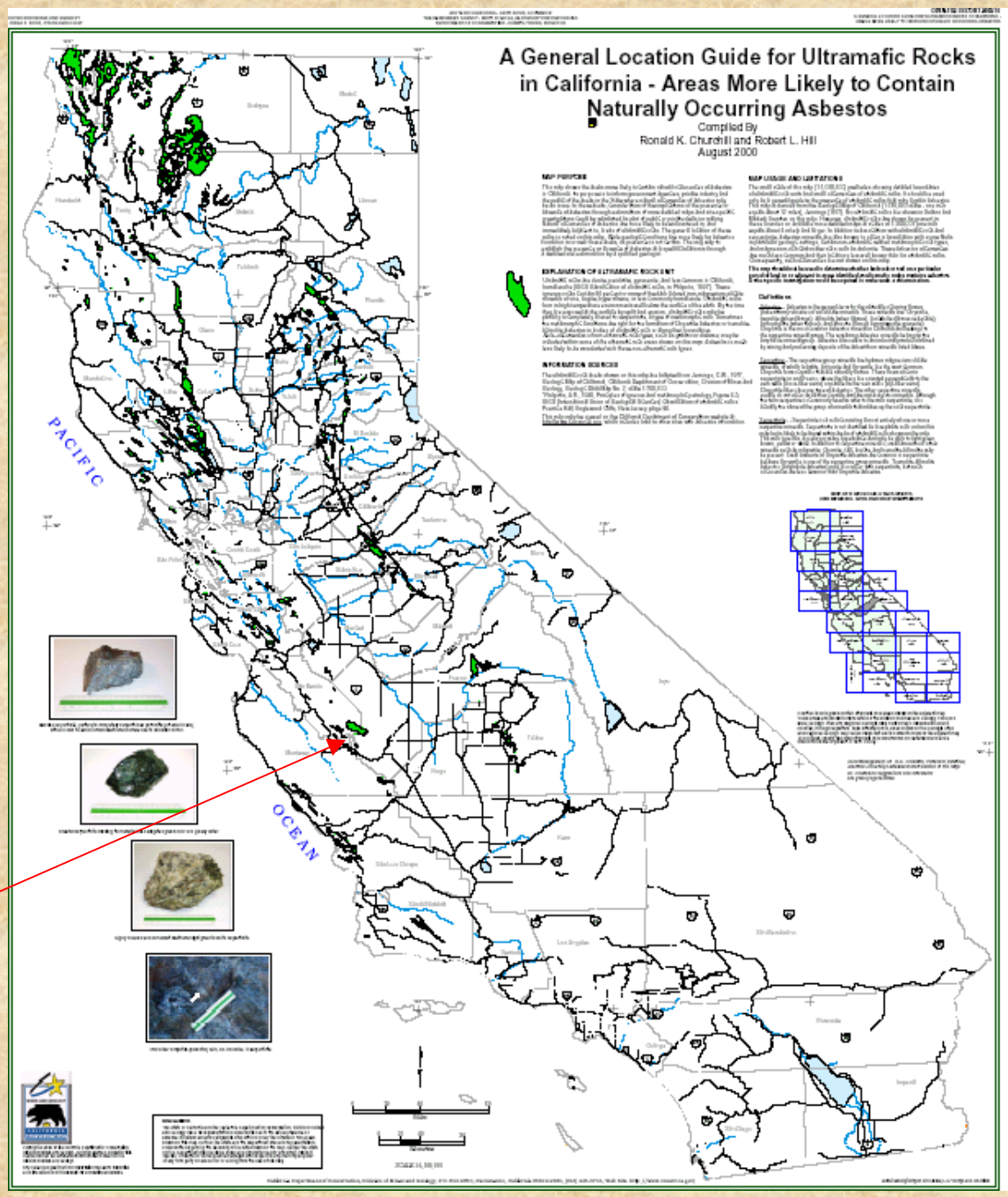
Serpentinite and/or ultramafic rock are known to be present in 44 of California's 58 counties. These rocks are particularly abundant in the counties of the Sierra Nevada foothills, the Klamath Mountains, and Coast Ranges.



Only operating asbestos mine in the United States

Source: California Department of Conservation, Division of Mines and Geology

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U.S. asbestos at a glance

- Production in 2000 was about 5,300 metric tons
- Imports were about 14,600 metric tons
- Apparent consumption was estimated to be 14,600 metric tons
  - Essentially all the asbestos used was chrysotile
  - Principal end uses were roofing products (62%), gaskets (22%), and friction products (12%)

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Asbestos production, by country (Thousand metric tons)

	1995	1999
Russia (*)	800	683
Canada	524	311
China	447	329
Brazil	210	188
Kazakhstan	161	139
South Africa (1)	88	18
Others	470	330
Total	2,700	2,000
Notes: (1) South African production includes crocidolite; (*) estimate		
Source: British Geological Survey, World Mineral Statistics 1995-99		

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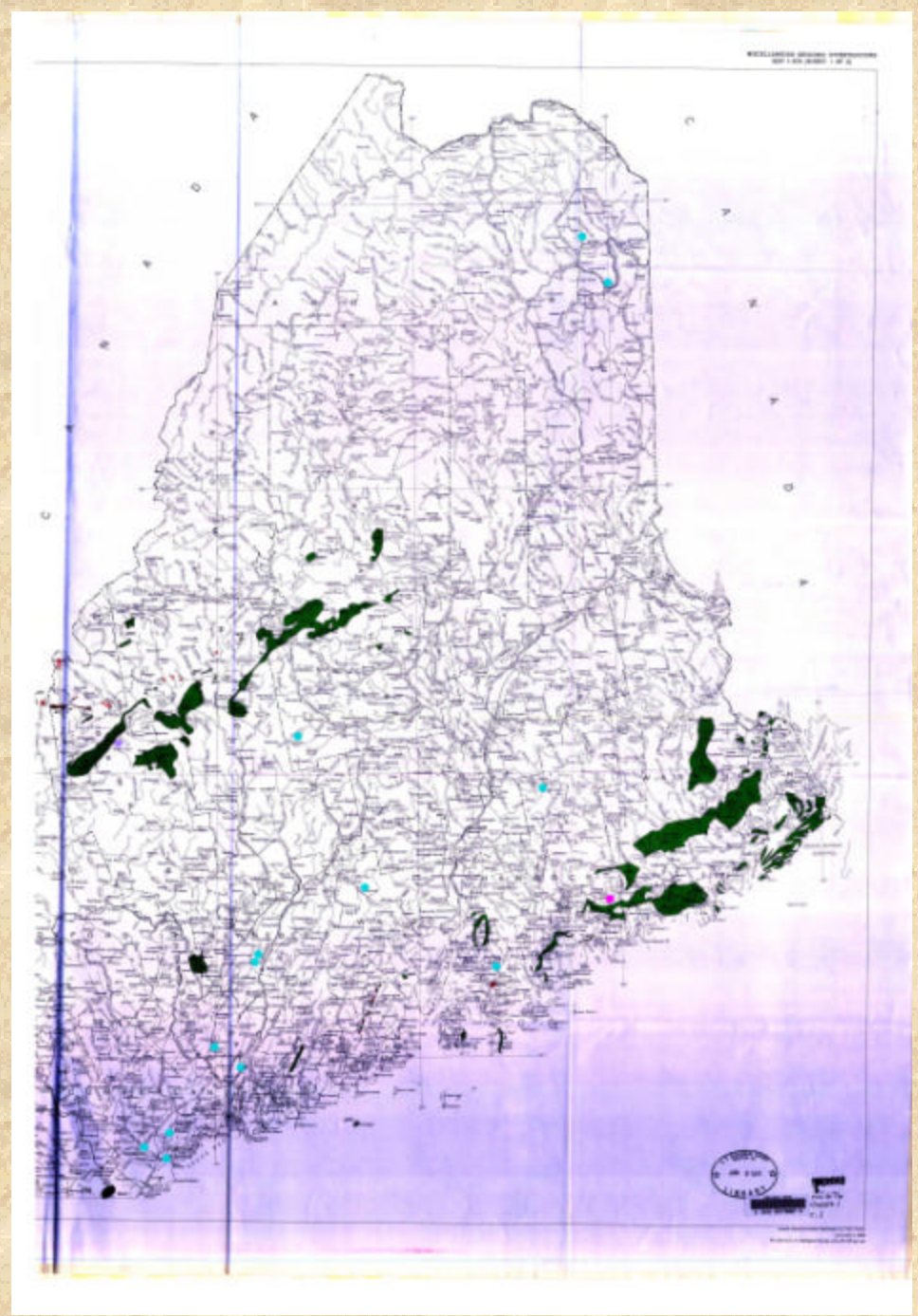
Crushed stone

- USGS does not report serpentinite separately; it is included in "miscellaneous stone"
  - Total quantity of miscellaneous stone reported in 1999 was slightly less than 34 million metric tons
  - Average value was estimated to be between $4 and $5 per metric ton for material used as roadbed aggregate

Maine



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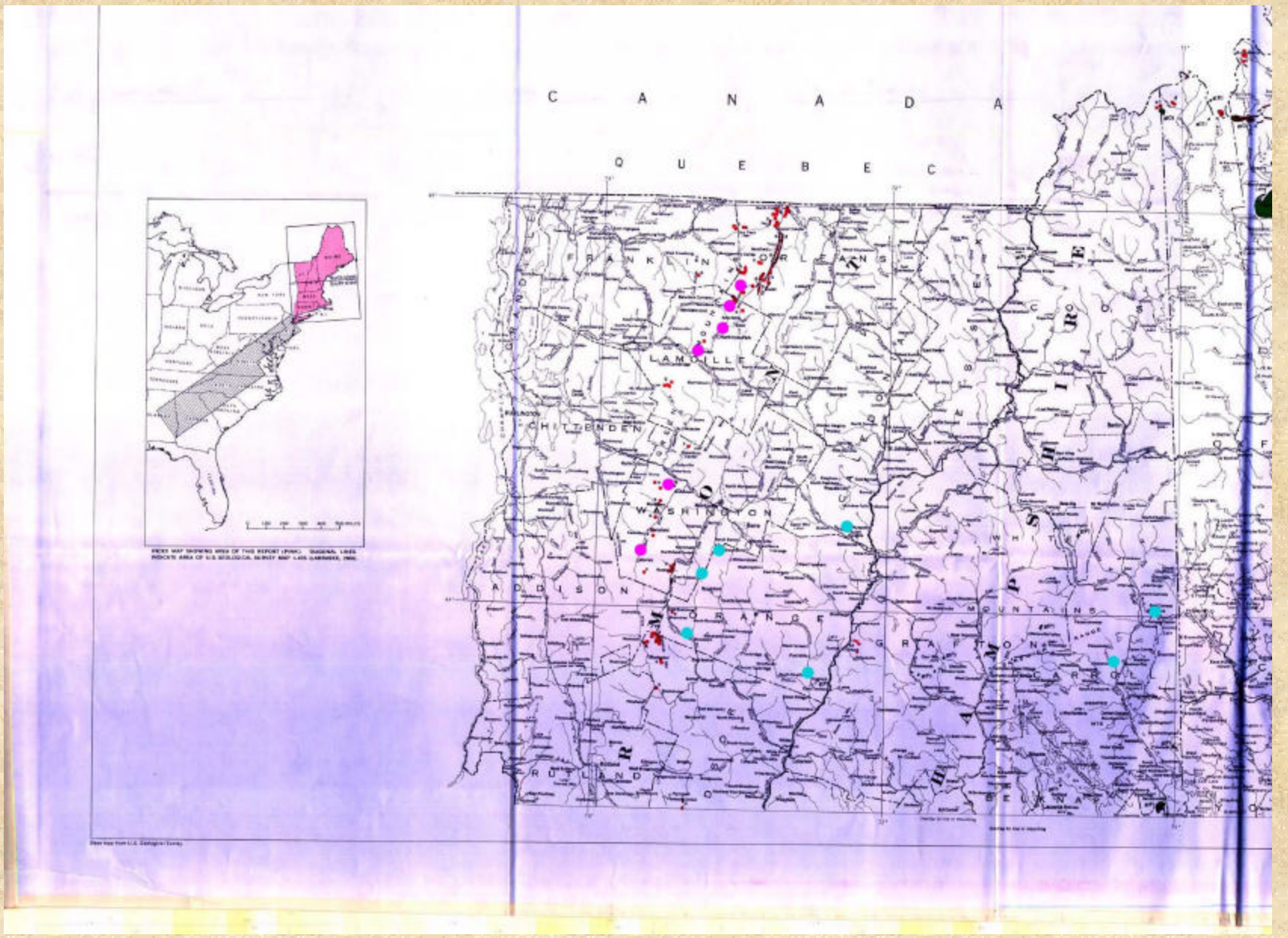

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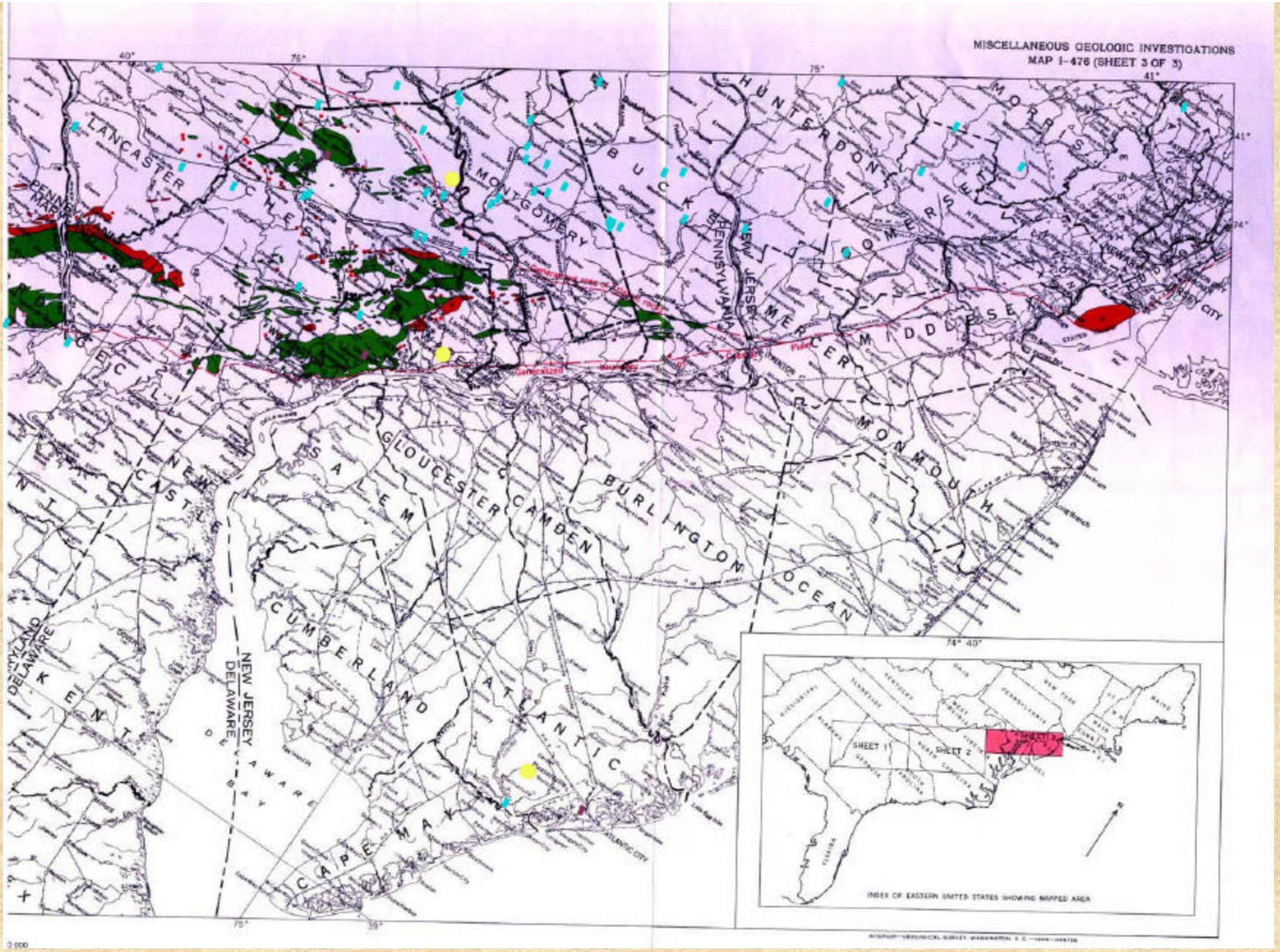
Parts of Vermont and New Hampshire



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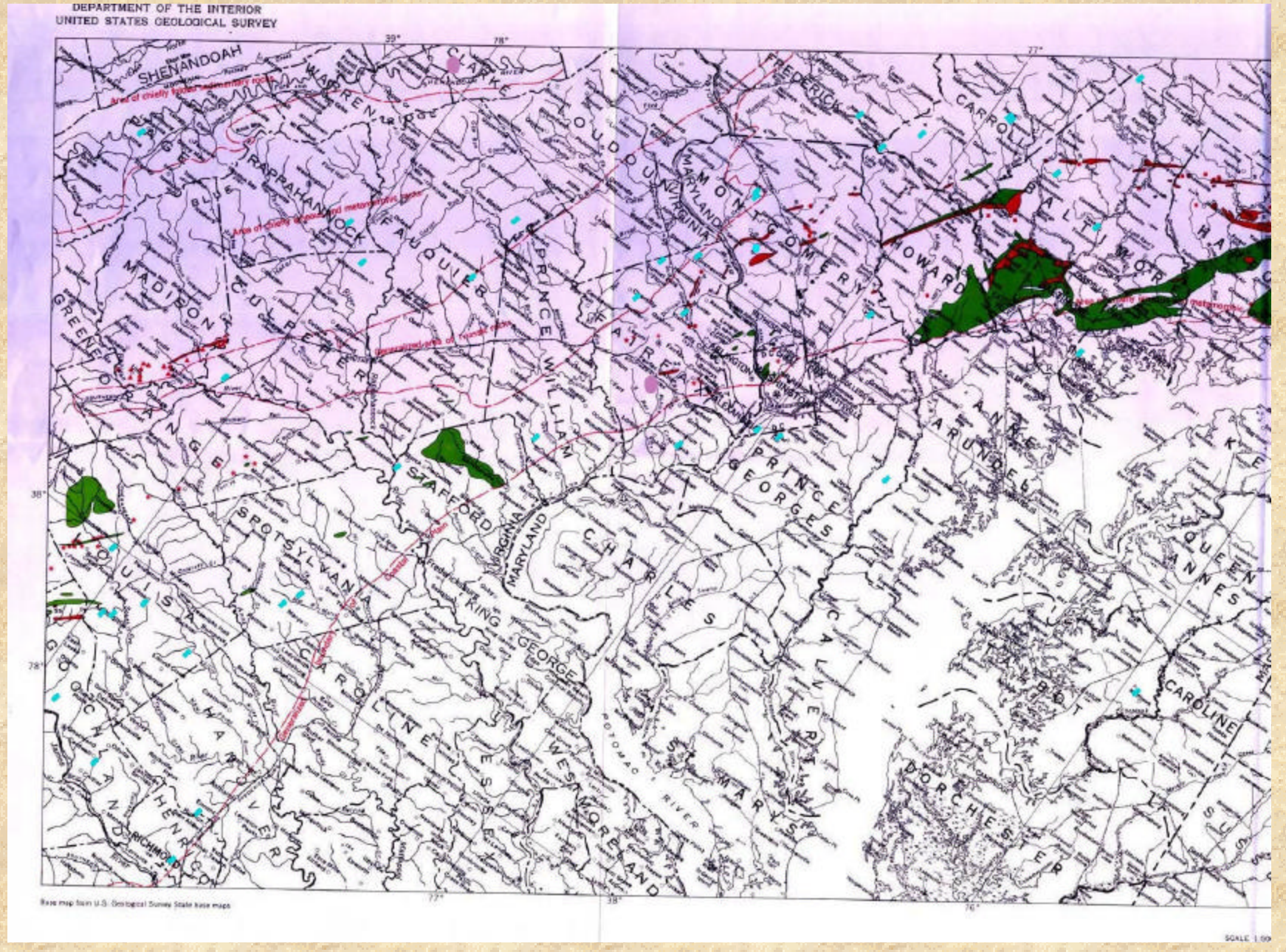
Parts of New Jersey, Delaware, Pennsylvania, and Maryland



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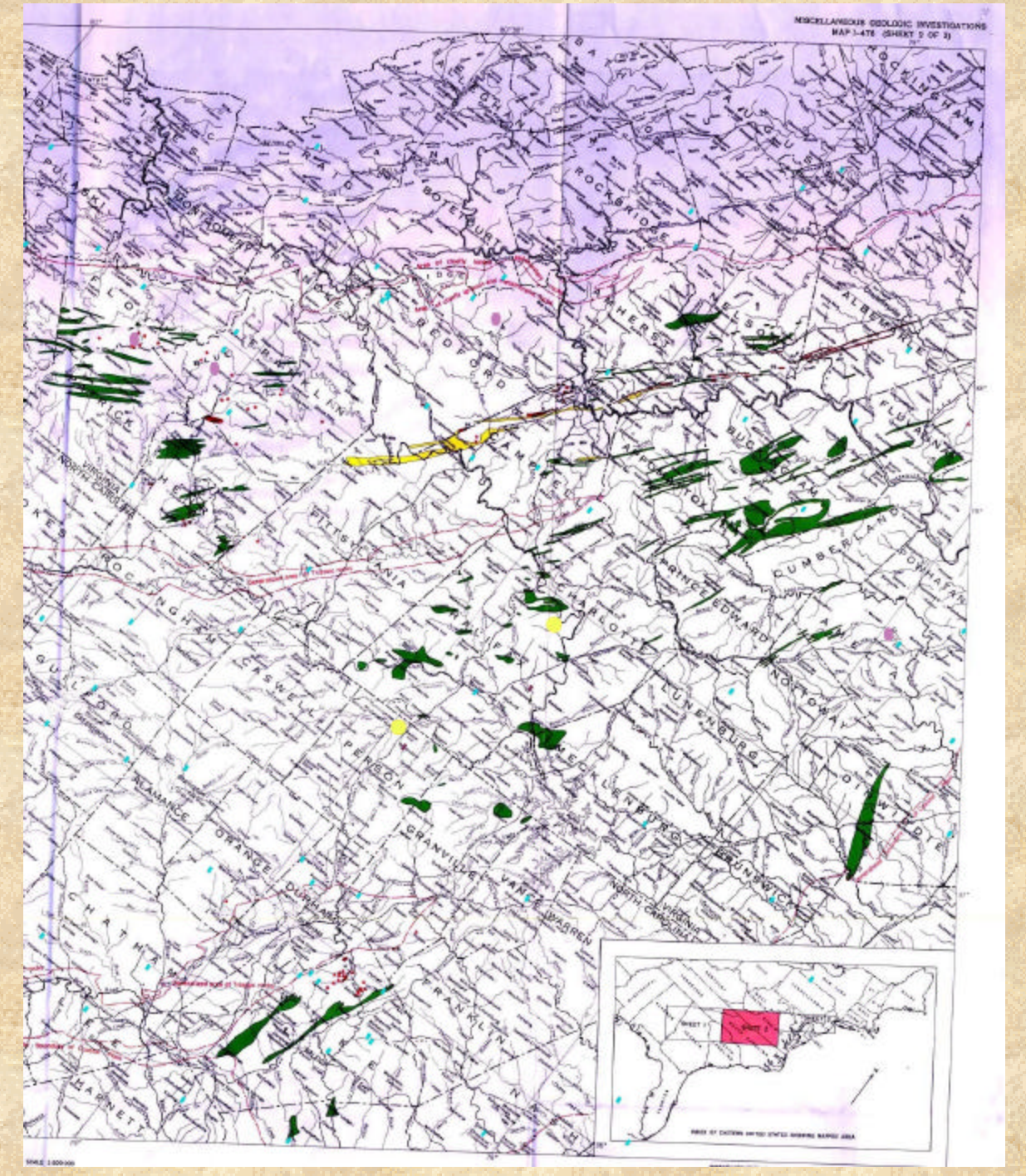
Parts of Maryland and Virginia

Parts of Virginia and North Carolina



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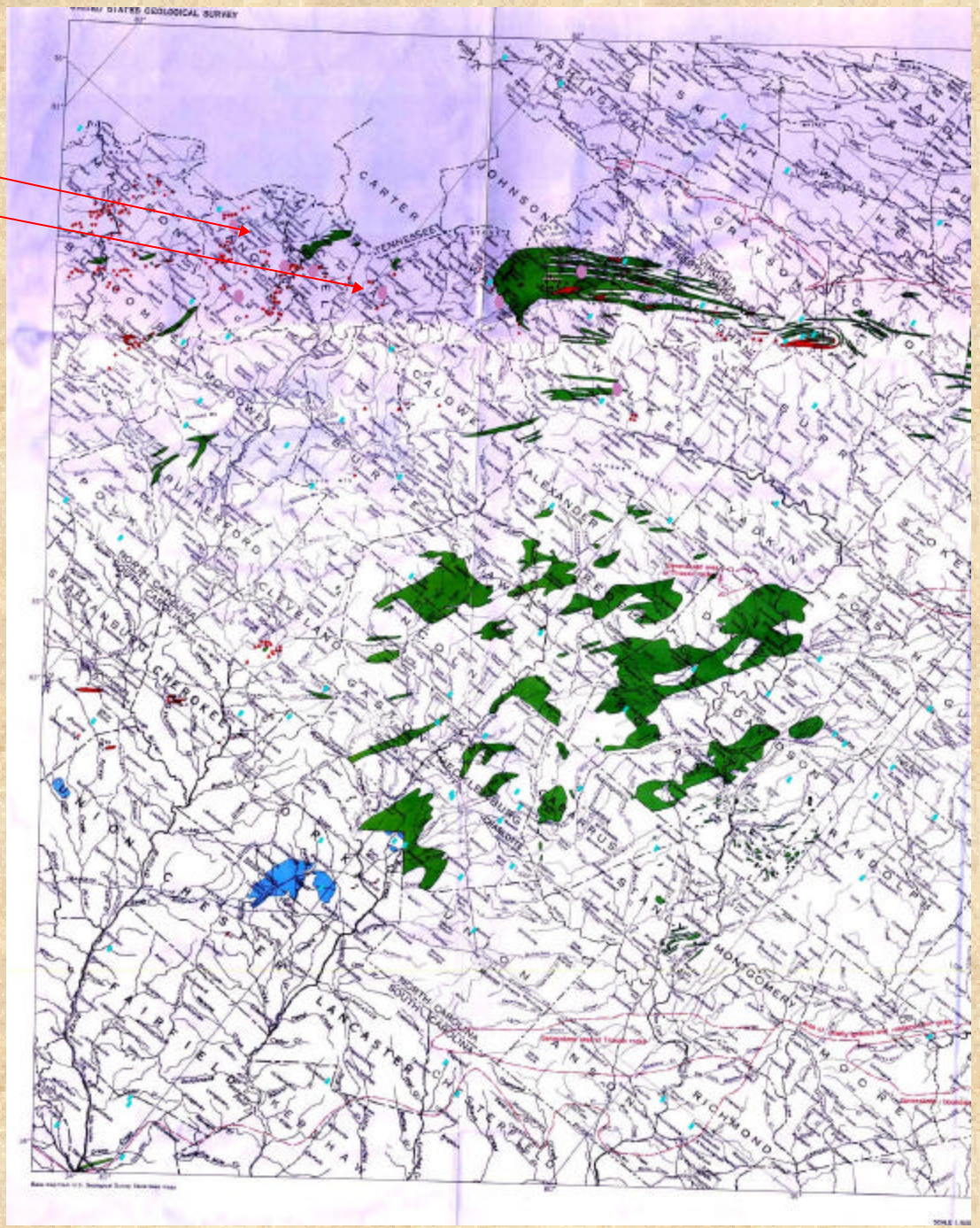
Unimin's olivine operations



Parts of North Carolina and South Carolina

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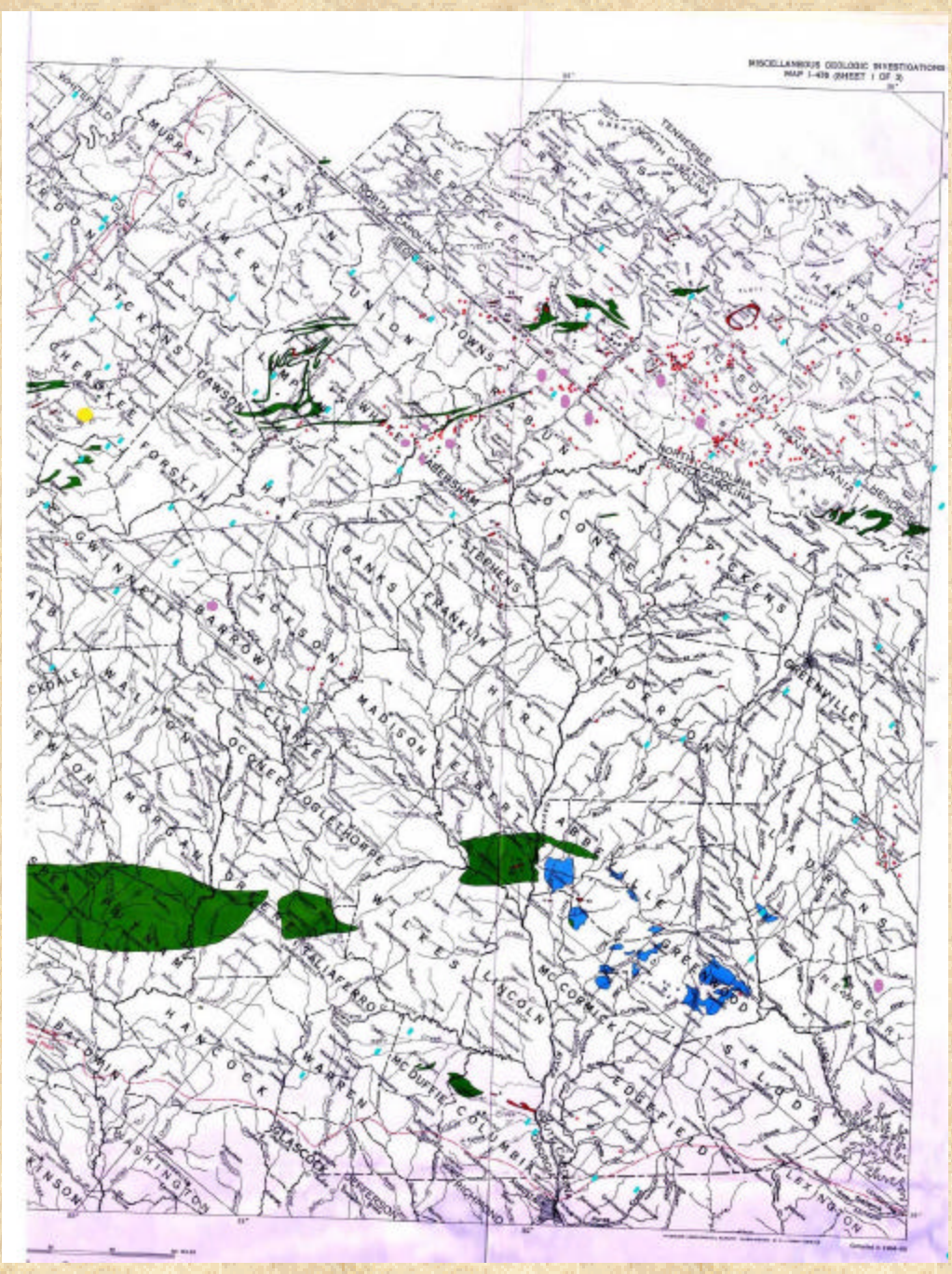
Parts of North Carolina, South Carolina, and Tennessee



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Parts of Georgia
and Alabama

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Potential resource issues

- Economic
  - Distance from deposit to power plant (transportation costs)
  - Competition from other end-use applications (aggregate vs. olivine)
  - Mining costs

Potential resource issues

- Environmental
  - Potential for asbestos occurrence in deposit
  - Disposal of magnesite and silica residue
    - Minor and trace mineral concentration
  - Land reclamation

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Potential resource issues

- Urbanization and development in the area
- Public perception

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