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OIL AND GAS EXPLORATION AND DEVELOPMENT, 1988
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Information for contributors
Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects related to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment, a file copy on 5½-in. diskette may be submitted in addition to the paper copies. Graphic illustrations should be camera-ready; photographs should be black-and-white glossy. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual Suggestions to Authors, 6th ed., 1976). The bibliography should be limited to “References Cited.” Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the “Acknowledgments.”

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTOS
These photos of concrete structures in Oregon were made available to us by the Oregon Concrete and Aggregate Producers Association (OCAPA). Clockwise, from top left: One Financial Center building in downtown Portland, Oregon (Photo by Strode Eckert Photographic); Portland Center for the Performing Arts; interior of the State of Oregon Revenue Building in Salem; the Marquess Castle, a private residence in Creswell, Oregon.

OIL AND GAS NEWS
Mist Gas Field map revised
The map of Mist Gas Field published by the Oregon Department of Geology and Mineral Industries (DOGAMI) is now available with all 1988 changes included. Among these changes is the addition of 13 wells driled by ARCO in the field and 5 service wells driled by Oregon Natural Gas Development for its gas-storage project. The map is published at a scale of 1:24,000 as DOGAMI Open-File Report 089-2 and sells for $5.00.

1989 legislation
DOGAMI is sponsoring legislation during the 1989 regular session of the Legislature including one bill related to oil and gas, HB-2089. This bill would give DOGAMI authority to write rules to oversee drilling of shallow holes such as seismic-shot holes, which are currently not covered in the law. No data derived from such holes would be collected, however. There is a strong movement to protect ground water in the state, and DOGAMI feels that such a program is best placed in this Department. The purpose of the bill is to provide for such ground-water protection and for surface cleanup. Once this legislation is adopted during the 1989 session, DOGAMI will initiate rulemaking for HB-2089, including public input.

Forum on the Geology of Industrial Minerals to be held in Portland
The Twenty-Fifth Forum on the Geology of Industrial Minerals will be held at the Portland Center Red Lion Inn in Portland from April 30 to May 2, 1989. The Forum, which meets annually to share information on the geology of industrial minerals, has met all over the United States but until this year has never met in the Pacific Northwest. For that reason, the industrial minerals of this region will be highlighted during the Forum.

Topics to be addressed during the day and a half of paper presentations include Oregon perlite, emery, talc, limestone, and bentonite; Washington olivine; Idaho garnet and perlite; Northwest diatomite, zeolite, and pumice; playa resources; and state and provincial summaries, including Oregon, Washington, Idaho, Montana, and British Columbia.

Following the sessions in Portland, a three-day field trip by bus has been planned to showcase the industrial mineral resources of Oregon. Overnight stops are planned for Baker, Ontario, and Bend. For additional information on the Forum, contact Ron Geitgey, Oregon Department of Geology and Mineral Industries, phone (503) 229-5580.

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OREGON GEOLOGY, VOLUME 51, NUMBER 2, MARCH 1989

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MINING ACTIVITY AND EXPLORATION IN OREGON, 1988

by Mark L. Ferns, Baker Field Office, Oregon Department of Geology and Mineral Industries

INTRODUCTION

The pace of exploration and mining activity continued to increase in 1988. Preliminary estimates by the U.S. Bureau of Mines place the value of 1988 nonfuel mineral production at $169 million, an increase of $9 million from 1987. Total mineral production including natural gas was over $175 million.

Over 605 mine sites were active during 1988. The majority, about 575, were sand-and-gravel and crushed-stone operations. The rest were industrial-mineral and small precious-metal mines.

Precious-metal exploration programs continued to increase in 1988. Over 40 companies were actively searching for gold deposits in the State. The main area of interest continued to be the Basin and Range Province in southeastern Oregon, including Malheur County, where over 5000 new claims were staked in 1988.

PRODUCTION

Industrial minerals continued to be an important part of the State's mineral industry. Ash Grove Cement West (active mine site 6) continued to produce crushed agricultural limestone and cement at the Durkee plant in Baker County. Ash Grove is the second-largest payer of property tax in the county and currently employs about 100 people.

Eagle-Picher Minerals, Inc., continued production of filter-grade diatomite at its facility in Malheur County. Diatomite for the plant is mined from Miocene lake sediments along the Malheur-Harney County line.

OREGON'S MINERAL PRODUCTION

<table>
<thead>
<tr>
<th>Year</th>
<th>Sand &amp; Gravel</th>
<th>Stone</th>
<th>Cement, Nickel, Pumice, etc.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>54</td>
<td>22</td>
<td>0</td>
<td>76</td>
</tr>
<tr>
<td>1973</td>
<td>55</td>
<td>38</td>
<td>0</td>
<td>81</td>
</tr>
<tr>
<td>1974</td>
<td>75</td>
<td>39</td>
<td>0</td>
<td>104</td>
</tr>
<tr>
<td>1975</td>
<td>73</td>
<td>30</td>
<td>0</td>
<td>106</td>
</tr>
<tr>
<td>1976</td>
<td>77</td>
<td>35</td>
<td>0</td>
<td>112</td>
</tr>
<tr>
<td>1977</td>
<td>74</td>
<td>35</td>
<td>0</td>
<td>108</td>
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<tr>
<td>1978</td>
<td>84</td>
<td>44</td>
<td>0</td>
<td>128</td>
</tr>
<tr>
<td>1979</td>
<td>111</td>
<td>54</td>
<td>+</td>
<td>165</td>
</tr>
<tr>
<td>1980</td>
<td>85</td>
<td>65</td>
<td>12</td>
<td>172</td>
</tr>
<tr>
<td>1981</td>
<td>85</td>
<td>65</td>
<td>13</td>
<td>163</td>
</tr>
<tr>
<td>1982</td>
<td>73</td>
<td>37</td>
<td>10</td>
<td>120</td>
</tr>
<tr>
<td>1983</td>
<td>82</td>
<td>41</td>
<td>10</td>
<td>133</td>
</tr>
<tr>
<td>1984</td>
<td>75</td>
<td>46</td>
<td>8</td>
<td>129</td>
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<tr>
<td>1985</td>
<td>91</td>
<td>39</td>
<td>10</td>
<td>140</td>
</tr>
<tr>
<td>1986</td>
<td>96</td>
<td>30</td>
<td>9</td>
<td>135</td>
</tr>
<tr>
<td>1987</td>
<td>102</td>
<td>52</td>
<td>6</td>
<td>160</td>
</tr>
<tr>
<td>1988</td>
<td>114</td>
<td>55</td>
<td>6</td>
<td>175</td>
</tr>
</tbody>
</table>


Precious-metal production continued to be small, coming mainly from small placer mines in southwestern and northeastern Oregon. The main producer was again the Bonanza Mine (active mine site 7) on Pine Creek near Halfway in Baker County.

Dry-land dredge plant in operation at Bonanza Mine (active mine site 7) in Baker County.
## Map

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Location</th>
<th>Commodity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pyx Mine</td>
<td>Sec. 1 T. 10 S., R. 35 E.</td>
<td>Lode gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grant County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Lower Grandview Mine</td>
<td>Sec. 6 T. 14 S., R. 37 E.</td>
<td>Lode gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baker County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Pine Creek area</td>
<td>T. 12 S., R. 38 E.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baker County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dooley Mountain area</td>
<td>Tps. 11, 12 S.</td>
<td>Perlite</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R. 40 E.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Clarks Creek area</td>
<td>Sec. 12 T. 13 S., R. 41 E.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baker County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Ash Grove Cement West</td>
<td>Sec. 11 T. 12 S., R. 43 E.</td>
<td>Crushed limestone and cement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baker County</td>
<td>Estimated at over 2.5 million. Employs around 100 people.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Bonanza Mining Co.</td>
<td>Sec. 3 T. 7 S., R. 45 E.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baker County</td>
<td>Largest placer mine in Oregon with over 20 employees.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cascade Pumice/Central Oregon Pumice</td>
<td>T. 17, 18 S. R. 11 E.</td>
<td>Pumice</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deschutes County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Oil-Dri Production Co.</td>
<td>Secs. 14, 21, 23 T. 27 S., R. 16 E.</td>
<td>Diatomite</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lake County</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Limestone quarry (background) and cement plant of Ash Grove Cement West, Inc., located south of Durkee, Baker County (active mine site 6).**

## Table 1. Active mines in Oregon, 1988—continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Location</th>
<th>Commodity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Teague Mineral Products</td>
<td>Secs. 8, 28, 29 T. 23 S., R. 46 E.</td>
<td>Bentonite clay and clinochlore zeolite</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Malheur County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>CooSand Corporation</td>
<td>Sec. 34 T. 24 S., R. 13 W.</td>
<td>Silica sand</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coos County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Coyote Creek area</td>
<td>Sec. 24 T. 33 S., R. 6 W.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Josephine County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Lower Grave Creek area</td>
<td>Secs. 31, 32 T. 33 S., R. 7 W.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Josephine County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Galice area</td>
<td>Tps. 34, 35 S. R. 8 W.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Josephine County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Josephine Creek area</td>
<td>Tps. 38, 39 S. R. 9 W.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Josephine County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Sucker Creek area</td>
<td>Tps. 39, 40 S. Rs. 6, 7 W.</td>
<td>Placer gold</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Josephine County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Jones Marble</td>
<td>Sec. 31 T. 38 S., R. 5 W.</td>
<td>Limestone</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Josephine County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Bristol Silica and Lime Co.</td>
<td>Sec. 30 T. 36 S., R. 3 W.</td>
<td>Silica</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jackson County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Steatite of Southern Oregon</td>
<td>Secs. 10, II T. 41 S., R. 3 W.</td>
<td>Soapstone</td>
<td>—</td>
</tr>
</tbody>
</table>

## Exploration

Exploration for precious metals, mainly gold, continued on an upswing in 1988. Over 40 companies were searching for the yellow metal by year's end.

The main area of interest in late 1988 was the Vale-Weiser area in northern and central Malheur County. This area, which lies at the intersection of the northern Basin and Range Province and the western edge of the Snake River Plain, is emerging as a highly promising epithermal-gold province.

A "rush" was triggered when Atlas Corporation announced a major discovery at its Grassy Mountain prospect (exploration site 20) south of Vale. Published geologic gold reserves are over 1 million oz at an average grade of 0.065 oz per short ton. The deposit is an epithermal (hot-springs-type) system in middle Miocene arkosic sandstones. Despite heavy snows, Atlas continued an extensive drilling program through the winter and completed more than 70 reverse-circulation holes by mid-November.

Much of the region adjacent to Grassy Mountain is undergoing extensive exploration. Other active prospects near Vale include Hope Butte (exploration site 14), Kerby (exploration site 15), Vale Buttes (exploration site 16), Double Mountain (exploration site 17), Harper Basin (exploration site 18), Shell Rock Butte (exploration site 19), (Continued on page 31)
<table>
<thead>
<tr>
<th>Map no.</th>
<th>Name</th>
<th>Location</th>
<th>Commodity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Herculaneum Mine</td>
<td>Sec. 22, T. 8 S., R. 36 E., Baker County</td>
<td>Gold and base metals</td>
<td>Exploration and development program by Cable Cove Mining Co.</td>
</tr>
<tr>
<td>2</td>
<td>Virtue Mine</td>
<td>T. 9 S., R. 41 E., Baker County</td>
<td>Gold</td>
<td>Drill programs by Hecla at the Flagstaff and by Morris &amp; Knudson at the Gray Eagle and Rachel.</td>
</tr>
<tr>
<td>3</td>
<td>East Eagle Mine</td>
<td>Secs. 19, 20, T. 7 S., R. 44 E., Crook County</td>
<td>Gold</td>
<td>COMINCO American continuing small exploration program.</td>
</tr>
<tr>
<td>4</td>
<td>Ochoco Mine</td>
<td>Secs. 29, 30, T. 13 S., R. 20 E., Malheur County</td>
<td>Gold</td>
<td>Continued exploration by Orbach.</td>
</tr>
<tr>
<td>5</td>
<td>Spanish Gulch</td>
<td>T. 13 S., R. 25 E., Wheeler County</td>
<td>Gold</td>
<td>Evaluation program by ASARCO.</td>
</tr>
<tr>
<td>6</td>
<td>Prairie Diggins prospect</td>
<td>Sec. 33, T. 13 S., R. 32 E., Grant County</td>
<td>Gold</td>
<td>Exploration program by Goldsearch.</td>
</tr>
<tr>
<td>7</td>
<td>Record Mine</td>
<td>Secs. 1, 2, T. 14 S., R. 36 E., Baker County</td>
<td>Gold</td>
<td>Exploration program by ICAN.</td>
</tr>
<tr>
<td>8</td>
<td>Malheur City area</td>
<td>T. 13 S., R. 41 E., Malheur County</td>
<td>Gold</td>
<td>Exploration programs by ICAN and Goldsearch.</td>
</tr>
<tr>
<td>9</td>
<td>Bear Creek area</td>
<td>Tps. 18, 19 S., R. 18 E., Crook County</td>
<td>Gold</td>
<td>Exploration and drilling program by Freeport-McMoran.</td>
</tr>
<tr>
<td>10</td>
<td>Glass Buttes</td>
<td>T. 24 S., R. 23 E., Lake County</td>
<td>Gold</td>
<td>Drilled and later dropped by Galactic.</td>
</tr>
<tr>
<td>12</td>
<td>Drewsey area</td>
<td>Tps. 20, 21 S., R. 34, 35 E., Harney County</td>
<td>Gold</td>
<td>Exploration and evaluation programs by Corona Gold and Reserve Industries.</td>
</tr>
<tr>
<td>13</td>
<td>Castle Rock</td>
<td>Secs. 8, 9, T. 18 S., R. 37 E., Malheur County</td>
<td>Gold</td>
<td>Under evaluation by Chevron.</td>
</tr>
<tr>
<td>14</td>
<td>Hope Butte</td>
<td>Sec. 21, T. 17 S., R. 43 E., Malheur County</td>
<td>Gold</td>
<td>Drilling program by Chevron.</td>
</tr>
<tr>
<td>15</td>
<td>Kerby</td>
<td>Secs. 22, 27, T. 15 S., R. 45 E., Malheur County</td>
<td>Gold</td>
<td>Intensive drilling program by Malheur Mining Co. Feasibility studies underway.</td>
</tr>
<tr>
<td>17</td>
<td>Double Mountain</td>
<td>T. 20 S., R. 44 E., Gold</td>
<td>Gold</td>
<td>Exploration program by AGNC.</td>
</tr>
<tr>
<td>18</td>
<td>Harper Basin</td>
<td>T. 21 S., R. 42 E., Gold</td>
<td>Malheur County</td>
<td>Exploration program by McDermitt Mines JV.</td>
</tr>
</tbody>
</table>

Table 2. Exploration sites and areas in Oregon, 1988—continued

<table>
<thead>
<tr>
<th>Map no.</th>
<th>Name</th>
<th>Location</th>
<th>Commodity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Shell Rock Butte</td>
<td>T. 21 S., R. 44, 45 E., Malheur County</td>
<td>Gold</td>
<td>Under evaluation by ASARCO.</td>
</tr>
<tr>
<td>20</td>
<td>Grassy Mountain</td>
<td>Sec. 8, T. 22 S., R. 44 E., Malheur County</td>
<td>Gold</td>
<td>Major discovery announced by Atlas.</td>
</tr>
<tr>
<td>21</td>
<td>Quartz Mountain</td>
<td>Sec. 6, T. 25 S., R. 43 E., Malheur County</td>
<td>Gold</td>
<td>Drilling program by Chevron.</td>
</tr>
<tr>
<td>22</td>
<td>Red Butte</td>
<td>T. 25 S., R. 43 E., Malheur County</td>
<td>Gold</td>
<td>Sampling program by Chevron.</td>
</tr>
<tr>
<td>23</td>
<td>Kaye</td>
<td>Tps. 23, 24 S., R. 45 E., Malheur County</td>
<td>Gold</td>
<td>Drilling program by Manville.</td>
</tr>
<tr>
<td>24</td>
<td>Bannock prospect</td>
<td>Sec. 11, T. 26 S., R. 45 E., Malheur County</td>
<td>Gold</td>
<td>Under evaluation by Chevron.</td>
</tr>
<tr>
<td>25</td>
<td>Mahogany prospect</td>
<td>Secs. 25, 26, T. 26 S., R. 46 E., Malheur County</td>
<td>Gold</td>
<td>Drilling program by Chevron.</td>
</tr>
<tr>
<td>26</td>
<td>Goff Mine</td>
<td>Secs. 20, 29, 30, T. 33 S., R. 7 W., Josephine County</td>
<td>Gold, silver, copper</td>
<td>Continued evaluation program by Amseal/BP America.</td>
</tr>
<tr>
<td>27</td>
<td>Silver Peak Mine</td>
<td>Sec. 23, T. 31 S., R. 6 W., Douglas County</td>
<td>Gold, silver, copper, platinum</td>
<td>Drilling program by Formosa.</td>
</tr>
<tr>
<td>28</td>
<td>Shanrock Mine</td>
<td>Sec. 19, T. 34 S., R. 2 W., Jackson County</td>
<td>Gold, silver, copper, platinum</td>
<td>Exploration programs by Freeport and Boise Cascade.</td>
</tr>
<tr>
<td>29</td>
<td>Shale City</td>
<td>T. 38 S., R. 2 E., Jackson County</td>
<td>Gold</td>
<td>Drilling program by Boise Cascade.</td>
</tr>
<tr>
<td>30</td>
<td>Quartz Mountain</td>
<td>Secs. 26, 27, 34, 35, T. 37 S., R. 36 E., Lake County</td>
<td>Gold</td>
<td>Feasibility studies underway; evaluation of leach tests and engineering studies.</td>
</tr>
<tr>
<td>31</td>
<td>Paisley area</td>
<td>T. 34 S., R. 18, 19 E., Lake County</td>
<td>Gold</td>
<td>Joint-venture exploration program by Dergstrom and Inland Gold &amp; Silver Corp.</td>
</tr>
<tr>
<td>32</td>
<td>Salt Creek</td>
<td>T. 38 S., R. 21 E., Gold</td>
<td>Lake County</td>
<td>Drilling program by FMC.</td>
</tr>
<tr>
<td>33</td>
<td>Pueblo Mountains area</td>
<td>Tps. 39, 40, 41 S., R. 34, 35 E., Malheur County</td>
<td>Gold</td>
<td>Exploration programs by Lake Fork and Red Arrow Resources.</td>
</tr>
<tr>
<td>34</td>
<td>Whitehorse area</td>
<td>T. 37 S., R. 26 E., Malheur County</td>
<td>Gold</td>
<td>Exploration program by Pegasus.</td>
</tr>
<tr>
<td>35</td>
<td>Flagstaff Butte</td>
<td>T. 38, 39 S., R. 37 E., Harney County</td>
<td>Gold</td>
<td>Exploration program by Geomex Minerals.</td>
</tr>
<tr>
<td>36</td>
<td>McDermitt area</td>
<td>Tps. 40, 41 S., R. 40 E., Malheur County</td>
<td>Gold</td>
<td>Exploration program by McDermitt Mines JV.</td>
</tr>
</tbody>
</table>
Mining and mineral exploration in Oregon in 1988 (excluding sand and gravel and stone). Active mines are keyed to Table 1; exploration sites and areas are keyed to Table 2.
Quartz Mountain (exploration site 21), Red Butte (exploration site 22), Katey (exploration site 23), and Mahogany (exploration site 25). A number of additional prospects had been located by year’s end (see location map of Vale-Weiser area). These include both middle Miocene sediment- and volcanic-hosted Basin and Range systems and early Pliocene systems related to development of the Snake River Plain.

The geology is complex in this part of Oregon, from which precious metals have not been previously produced. Geologists of the Oregon Department of Geology and Mineral Industries (DOGAMI), the U.S. Geological Survey, and Portland State University are currently conducting mapping programs to generate 1:24,000-scale geologic maps of the region.

DOGAMI has published maps of two quadrangles: Owyhee Ridge (GMS-53) and Graveyard Point (GMS-54). Publication is in progress on two more quadrangles: Owyhee Dam (GMS-55) and Adrian (GMS-56). Preliminary, unedited versions of the Grassy Mountain and Double Mountain quadrangles (GMS-57 and GMS-58, respectively) are available for inspection at the DOGAMI offices in Baker, Grants Pass, and Portland, and final versions of these two maps will be published later this year.

Elsewhere in the state, Tertiary volcanic-hosted epithermal systems continued to be the main focus of exploration. Areas of interest include south-central and central Oregon. Quartz Mountain Gold Corporation continued to reevaluate its Quartz Mountain prospect (exploration site 30) in Lake County. Metallurgical testing continued on samples from the property, which is reported to contain a resource of 10 to 15 million tons grading 0.04 oz of gold per ton. The company put down 50 drill holes in 1988 to obtain samples for further metallurgical testing.
Volcanogenic sulfide deposits in the older pre-Tertiary terranes of northeastern and southwestern Oregon continued to attract interest. Main areas of exploration continue to be the Goff (exploration site 26) and Silver Peak (exploration site 27) Mines in southwestern Oregon. Quartz veins in pre-Tertiary rocks also continued to be of some interest. Serpentinite-associated systems in northeastern Oregon, such as Spanish Gulch (exploration site 5), the Prairie Diggings prospect (exploration site 6), the Record Mine (exploration site 7), and the Malheur City area (exploration site 8) drew the most attention last year.

The search for industrial minerals also continued in 1988. Perlite and diatomite were again of dominant interest to the exploration industry. Other sought-after commodities included bentonite clay, zeolite, and talc.

In July 1988, the Oregon Department of Geology and Mineral Industries published a comprehensive study of talc in Oregon (DOGAMI Special Paper 18). Similar reports on bentonite (Special Paper 20) and limestone (Special Paper 19) are scheduled for publication this spring and later this year, respectively.

Send us your announcements

One of our Medford readers has suggested that Oregon Geology serve as a clearing house for announcements on geological training sessions, workshops, or seminars for the professional geologist.

We think that is a good idea. So if you send us notices of your meetings and training sessions, we will print them in Oregon Geology, space permitting. Allow at least a month and a half—and preferably two months—lead time.
Oil and gas exploration and development in Oregon, 1988

by Dennis L. Olmstead, Petroleum Engineer, and Dan E. Wermiel, Petroleum Geologist, Oregon Department of Geology and Mineral Industries

ABSTRACT

Oil and gas lease activity made a poor showing in 1988, but drilling was up 37 percent over 1987. One County, one State, and one Federal lease sale were held during the year, but a combined total of only 27,672 acres was taken at the three sales.

Mist Gas Field and vicinity had 13 wells and three redrills by ARCO Oil and Gas Company. Seven of the ARCO wells were successful, for a cumulative flow rate of 5.0 million cubic feet per day (MMcfd). The field now has fourteen producers making 9.1 MMcfd. Production value for the year was $6.4 million. ARCO also drilled a deep test in Morrow County.

Oregon Natural Gas Development Company drilled five gas-storage service wells at Mist to complete the drilling on their two-pool storage project. Surface-equipment engineering and construction were also carried out. Gas withdrawals will begin in the fall of 1989.

Northwest Natural Gas Company received approval to build a new 50-mi-long gas pipeline from Mist to Portland. Construction will take place in 1989.

The Department of Geology and Mineral Industries (DOGAMI) began a five-year study of the Tyee Basin in western Douglas and eastern Coos Counties. Emphasis will be on source rock, stratigraphy, and structure of the rocks in the basin.

LEASING ACTIVITY

Leasing of public land in 1988 consisted of three public-lands lease sales plus over-the-counter leasing of Bureau of Land Management (BLM) property. The accompanying lease map shows major areas of leasing. It includes over 220,000 acres issued early in the year to Amoco and Conoco. This acreage appeared in our 1987 report because the filing dates back to December 1987.

The first lease sale of the year was held on June 16, 1988, by Columbia County. At the sale, 94 parcels were offered, comprising 32,407 acres, all in and around Mist Gas Field. Successful bidders were ARCO and Leadco, taking 29 parcels totaling 8,079 acres. The high bid was $51 per acre in sec. 20, T. 6 N., R. 5 W. Income to the County from the sale was about $145,000. The terms of Columbia County leases are as follows: primary term of ten years, thirteenth royalty, and annual rental of $10 per acre.

Major areas of public-lands leasing in 1988. Map shows acreage applied for and issued during the year. Most issued acreage is from 1986 and 1987 applications; only 5,000 acres were filed for in 1988. Withdrawals and terminations are not shown. Data courtesy of Dolores Yates, LANDATA.
### Table 1. Oil and gas permits and drilling activity in Oregon, 1988

<table>
<thead>
<tr>
<th>Permit no.</th>
<th>Operator, well, API number</th>
<th>Location</th>
<th>Status, depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>376 ARCO Columbia Co. 42-8-54, 36-009-00213</td>
<td>NE ¼ sec. 8, T. 5 N., R. 4 W., Columbia County</td>
<td>Completed, gas; TD: 2,255.</td>
<td></td>
</tr>
<tr>
<td>392 ARCO Longv. Fibre 32-20-65, 36-009-00229</td>
<td>NE ¼ sec. 20, T. 6 N., R. 5 W., Columbia County</td>
<td>Abandoned, dry hole; TD: 1,249.</td>
<td></td>
</tr>
<tr>
<td>397 ARCO Hanna 1, 36-049-00002</td>
<td>NE ¼ sec. 23, T. 2 S., R. 27 E., Morrow County</td>
<td>Abandoned, dry hole; TD: 9,211.</td>
<td></td>
</tr>
<tr>
<td>398 ARCO CFI 34-1-55, 36-009-00232</td>
<td>SE ¼ sec. 1, T. 5 N., R. 5 W., Columbia County</td>
<td>Completed, gas; TD: 1,370.</td>
<td></td>
</tr>
<tr>
<td>399 ARCO Johnston 44-19-65, 36-009-00233</td>
<td>SE ¼ sec. 19, T. 6 N., R. 5 W., Columbia County</td>
<td>Abandoned, dry hole; TD: 2,910.</td>
<td></td>
</tr>
<tr>
<td>400 ARCO Columbia Co. 12-19-65, 36-009-00234</td>
<td>NW ¼ sec. 19, T. 6 N., R. 5 W., Columbia County</td>
<td>Completed, gas; TD: 3,209.</td>
<td></td>
</tr>
<tr>
<td>401 Oregon Nat. Gas Dev. IW 42C-10, 36-009-00235</td>
<td>NE ¼ sec. 10, T. 6 N., R. 5 W., Columbia County</td>
<td>Completed, service well; TD: 2,769.</td>
<td></td>
</tr>
<tr>
<td>402 Oregon Nat. Gas Dev. IW 22D-10, 36-009-00236</td>
<td>NW ¼ sec. 10, T. 6 N., R. 5 W., Columbia County</td>
<td>Completed, service well; TD: 2,770.</td>
<td></td>
</tr>
<tr>
<td>403 Oregon Nat. Gas Dev. OM 43B-10, 36-009-00237</td>
<td>SE ¼ sec. 10, T. 6 N., R. 5 W., Columbia County</td>
<td>Completed, service well; TD: 2,766.</td>
<td></td>
</tr>
<tr>
<td>404 Oregon Nat. Gas Dev. IW 33D-3, 36-009-00238</td>
<td>SE ¼ sec. 3, T. 6 N., R. 5 W., Columbia County</td>
<td>Completed, service well; TD: 2,962.</td>
<td></td>
</tr>
<tr>
<td>405 Oregon Nat. Gas Dev. IW 23B-3, 36-009-00239</td>
<td>SW ¼ sec. 3, T. 6 N., R. 5 W., Columbia County</td>
<td>Completed, service well; TD: 2,974.</td>
<td></td>
</tr>
<tr>
<td>406 ARCO Columbia Co. 44-23-65, 36-009-00240</td>
<td>SE ¼ sec. 27, T. 6 N., R. 5 W., Columbia County</td>
<td>Completed, gas; TD: 2,150.</td>
<td></td>
</tr>
<tr>
<td>407 ARCO Columbia Co. 24-9-64, 36-009-00241</td>
<td>NW ¼ sec. 9, T. 6 N., R. 4 W., Columbia County</td>
<td>Completed, gas; TD: 2,503.</td>
<td></td>
</tr>
<tr>
<td>408 ARCO CFW 12-15-64, 36-009-00242</td>
<td>NW ¼ sec. 15, T. 6 N., R. 4 W., Columbia County</td>
<td>Completed, gas; TD: 1,950.</td>
<td></td>
</tr>
<tr>
<td>409 ARCO Benson 14-7-64, 36-009-00243</td>
<td>SW ¼ sec. 26, T. 6 N., R. 4 W., Columbia County</td>
<td>Abandoned, dry hole; TD: 2,506.</td>
<td></td>
</tr>
<tr>
<td>410 ARCO CFI 23-16-64, 36-009-00244</td>
<td>NW ¼ sec. 16, T. 6 N., R. 4 W., Columbia County</td>
<td>Abandoned, dry hole; TD: 1,775.</td>
<td></td>
</tr>
<tr>
<td>411 ARCO Hamlin 33-17-65, 36-009-00245</td>
<td>SE ¼ sec. 17, T. 6 N., R. 5 W., Columbia County</td>
<td>Permit issued; PTD: 2,835.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Permit no.</th>
<th>Operator, well, API number</th>
<th>Location</th>
<th>Status, depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>413 ARCO Columbia Co. 22-17-75, 36-009-00247</td>
<td>NW ¼ sec. 17, T. 7 N., R. 5 W., Columbia County</td>
<td>Permit issued; PTD: 3,250.</td>
<td></td>
</tr>
<tr>
<td>414 ARCO, Sterling 12-24-66 and Redrill 36-009-00019, 36-009-00019-01</td>
<td>NW ¼ sec. 12, T. 7 N., R. 6 W., Clatsop County</td>
<td>Abandoned, dry hole; TD: 3,444, RD: 2,845.</td>
<td></td>
</tr>
<tr>
<td>415 ARCO, Longview Fibre 24-8-75 and Redrill 36-009-00248, 36-009-00248-01</td>
<td>SW ¼ sec. 8, T. 6 N., R. 5 W., Columbia County</td>
<td>Abandoned, dry hole; TD: 2,814, RD: 3,039.</td>
<td></td>
</tr>
<tr>
<td>416 ARCO OR 13-33-86, 36-009-00020</td>
<td>NW ¼ sec. 33, T. 8 N., R. 6 W., Clatsop County</td>
<td>Permit issued; PTD: 6,000.</td>
<td></td>
</tr>
<tr>
<td>417 ARCO OR 13-33-86, 36-009-00021</td>
<td>SW ¼ sec. 33, T. 8 N., R. 6 W., Clatsop County</td>
<td>Permit issued; PTD: 6,000.</td>
<td></td>
</tr>
</tbody>
</table>

Drilling at the ARCO Hanna 1 well in the Columbia Basin, Morrow County.
BLM held a lease sale on September 7, offering 314,635 acres in 185 parcels. No bids were received, and the acreage was made available the following day for noncompetitive over-the-counter filing. Subsequently, applicants filed for four parcels consisting of 4,335 acres in central Oregon, at a total fee and rental cost of $6,802.

During 1988, several changes took place in the way BLM conducted its leasing program. The agency made modifications in the way over-the-counter filings may be made. Additional changes last year included initiation of quarterly lease sales by BLM, with the September 7 sale being the first on this schedule. Subsequent sales were scheduled for January 25 and March 1, 1989. The January 25 sale received no bids, while results of the March 1 sale were not available in time for this report. The 1988 rental income for Federal leases totaled $1,139,822, and at year's end, 876,135 acres in 397 parcels were under lease, an increase of 15 percent in leased acreage over the previous year.

The Oregon Division of State Lands held a lease sale on November 1, 1988, offering 19,553 acres in 43 parcels, mainly in Clatsop County. Successful bidders included ARCO (15,553 acres), and W. Cooper (3,200 acres). L. Fisk also took 800 acres in Wheeler County with no bidding. These leases were issued December 7, 1988. Fees and bonus payments totaled about $75,000 to the State.

Terminated Federal and State lease acreage totaled 324,535 acres.

**DRILLING**

Fourteen exploratory oil and gas wells, five gas storage wells, and three redrills were drilled in the state in 1988. This is a significant increase over the level of the 1987 drilling activity. All but one of the wells were drilled in the Mist Gas Field area, a pattern that has continued since the field was discovered in 1979. The other well was a wildcard well drilled by ARCO in the Columbia Basin of northeastern Oregon. This well, the Hanna 1, was the first well drilled for oil and gas in Morrow County and was a rare attempt to penetrate the volcanic rocks covering this geologic province and to reach the underlying strata that are interpreted to contain favorable conditions for oil and gas accumulation and entrapment. The well was drilled to a total depth of 9,211 ft, making it the deepest well drilled in Oregon during 1988, but was plugged and abandoned as a dry hole.

At Mist Gas Field, two operators were active during the year. As has been the case for the past several years, ARCO Oil and Gas Company was the most active operator, drilling 13 exploratory wells and three redrills. Of these, seven were successful gas completions, while the rest were dry holes. Oregon Natural Gas Development Corporation, a subsidiary of Northwest Natural Gas Company, drilled five wells as part of the natural-gas storage project. Details of these wells are provided in the natural-gas storage project portion of this summary.

Total footage drilled for the year, including the gas-storage wells, was 61,523 ft, a significant increase over the 42,665 ft drilled during 1987. The average depth per well was 2,797 ft, about the same as the average of 2,896 ft per well drilled the previous year.

During 1988, DOGAM issued 51 permits to drill (Table 1), while two expired permits were canceled, and three permits were denied during the year (Table 2).

**DISCOVERIES AND GAS PRODUCTION**

Mist Gas Field saw seven new producers, which ties last year's results as the record for the number of new gas wells discovered in a single year at Mist. ARCO Oil and Gas Company is the operator of all these wells, which include the CFI 34-1-55, CFW 12-15-64, and **Table 2. Canceled and denied permits, 1988**

<table>
<thead>
<tr>
<th>Permit number</th>
<th>Operator, well, API number</th>
<th>Location</th>
<th>Issue date</th>
<th>Cancellation date</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>356</td>
<td>ARCO Columbia Co. 13-21</td>
<td>SW¹/₂ sec. 21</td>
<td>3-28-86</td>
<td>3-28-86</td>
<td>Permit canceled; expired.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T. 6 N., R. 5 W.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Columbia County</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>369</td>
<td>ARCO CFI 31-22</td>
<td>NE¹/₂ sec. 22</td>
<td>7-18-86</td>
<td>7-18-86</td>
<td>Permit canceled; expired.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T. 6 N., R. 5 W.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Columbia County</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>396</td>
<td>Interwest Exploration</td>
<td>NE¹/₂ sec. 5</td>
<td>—</td>
<td>—</td>
<td>Permit denied; incomplete application.</td>
</tr>
<tr>
<td></td>
<td>Cavenham 31-5</td>
<td>T. 6 N., R. 7 W.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Clatsop County</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>415</td>
<td>ARCO Greenup 1</td>
<td>NE¹/₂ sec. 19</td>
<td>—</td>
<td>—</td>
<td>Permit denied; operator withdrew application.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T. 2 S., R. 28 E.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Morrow County</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>416</td>
<td>ARCO Greenup 2</td>
<td>NE¹/₂ sec. 20</td>
<td>—</td>
<td>—</td>
<td>Permit denied; operator withdrew application.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T. 2 S., R. 28 E.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Morrow County</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GAS STORAGE

Drilling for the Mist gas-storage project was completed by Northwest Natural Gas Company in 1988, adding to two previous years of storage- and monitor-well drilling. Five wells were drilled during the year—four injection-withdrawal wells and one observation-monitor well. Total footage drilled for these wells was 14,893 ft, for an average depth of 2,818 ft per well. Two of the injection-withdrawal wells were added to the Flora Pool and two were added to the Bruer Pool, completing a total of three injection-withdrawal wells for each of these pools. Injection-withdrawal wells are used to add gas to and remove gas from the storage reservoir.

During 1988, the Miller Natural Gas Station was being redesigned, and the only gas injection done during the year was during February, when 4.2 MMcf of gas was injected into the Bruer Pool to test the compressors at Miller Station. Withdrawals are scheduled to begin during fall 1989. The observation-monitor well was drilled on the southern edge of the storage area, bringing to seven the total number of observation-monitor wells drilled. Observation-monitor wells are used to monitor the gas levels and pressures in the storage reservoir. No additional drilling is expected at the gas-storage project at this time.

OTHER ACTIVITIES

DOGAMI began a five-year study of the Tyee Basin during 1988. The Tyee Basin is located in the southern Coast Range and contains Eocene sandstone strata that are believed to have similarities to the sands that produce gas at Mist Gas Field. The study area is located primarily in western Douglas and eastern Coos Counties. In the study, emphasis will be placed on those characteristics needed to generate and trap gas and oil, namely, source rock, stratigraphy, and structural framework. Funding for the study is being provided by landowners in the study area and by County, State and Federal agencies. DOGAMI will release publications reporting the results of the ongoing study to keep the public informed of its progress.

The Northwest Petroleum Association remained active during 1988, showing a membership of about 140 at year’s end. At monthly meetings, papers related to the oil and gas industry were presented, and a field symposium with a geologic field trip was held in May. The 1988 symposium took place in Ocean Shores, Washington, and included field trips to the Chehalis and Grays Harbor Basins as well as the coastal area of the Olympic Peninsula.

Northwest Natural Gas received approval from the Energy Facility Siting Council to build a natural-gas pipeline from the Mist Gas Field to Portland. The pipeline, the South Mist Feeder, will be of 16-in. steel, 50 mi long, and will extend from the Mist storage project to West Union Road, west of Portland, where it will connect with existing pipeline facilities. With the new pipeline, Northwest Natural Gas Company will increase deliverability when producing or storing gas. The line will also provide a back-up capability in the event the existing gas line needs to be turned off.

Offshore oil and gas exploration is still several years away in the region, but planning is underway at the State and Federal levels. The Oregon Ocean Resources Management Task Force, established by the 1987 Legislature, met six times and released an Interim Report. Public workshops were also held to gather input on the concept of planning for new uses of the ocean, primarily mineral development. The consensus from the public was that existing uses such as fishing and tourism should be preserved, whereas mining or oil and gas exploration should be prevented. Further meetings will result in a draft plan in September 1989, followed by additional public input. A final plan is scheduled for July 1990.

Meanwhile, the U.S. Minerals Management Service is moving ahead with its plans for an April 1992 oil and gas lease sale for the outer continental shelf off Oregon and Washington. The agency held a workshop in Portland in June 1988 to gather input about its environmental studies program in preparation for the sale. Several studies are underway, and more are planned for 1989 and 1990. Industry interest will not be gathered until November 1989 and may ultimately determine whether there will be a 1992 offering.

The Mist Gas Field map (1:24,000) has been updated as DOGAMI Open-File Report 88-9-2. It reflects all 1988 drilling activity in the field, including gas-storage and monitor-well activity.
The grandeur of concrete: Part I
by Don Dupras, Geologist, California Division of Mines and Geology

INTRODUCTION
Concrete literally forms the foundation of our society. Our homes, factories, offices, schools, roads, runways, dams, sewers—in short, our quality of life depends on inexpensive and abundant concrete (Figure 1). Engineers and architects utilize its versatility for thousands of specialty uses. The fire-resistant property of concrete is a structural advantage over wood; concrete does not burn or rot. Its insulating properties are widely employed to save on heating and cooling costs. The density of ordinary concrete enables it to store solar heat and to slowly release it at night. Concrete is relatively inexpensive, readily available, permanent, very durable, and easy to make; all that is needed is a mold and sufficient time for curing. As important as concrete is to our society, this triumph of human ingenuity is so commonplace that hardly anyone appreciates it.

EARLY HISTORY
As we casually use sidewalks, roads, and swimming pools, it is easy to overlook the distinguished lineage of concrete. Cement, the principal matrix material of concrete, has been utilized for over 5,000 years. The ancient Egyptians used a cement mortar made with heated or "calcined" gypsum in the construction of the great pyramids at Giza and other structures. Cement was used for the construction of the harbor at Kition, Cyprus, in about 600 B.C. (Stapleton, 1981; Encyclopedia Britannica, 1984).

Mediterranean area
Lime-based cement, a significant improvement over gypsum-based cement and quite similar to the cement used today, was used by the Mycenaeans and Phoenicians in about 500 B.C. The oldest lime cement so far discovered is in the ruins of a Phoenician temple on Cyprus (Draffin, 1943). Lime cement was made by calcining limestone and then crushing it to a fine powder. Gypsum required a calcining temperature of 300 to 400 °F. In contrast, lime required a calcining temperature of 1,500 to 1,650 °F. In the early lime calcining process, heated limestone (CaCO₃ + heat) produced carbon dioxide gas (CO₂) and lime (CaO). Water added to crushed lime causes a chemical reaction and results in firm hydrated lime cement (Ca(OH)₂). When mixed with water and sand, the lime cement made a durable mortar (Lea, 1970).

The use of lime cement spread from Crete to Greece, where it was used to line hand-dug cisterns and was mixed with sand and gravel to form a primitive concrete used in construction. From Greece, the use of lime cement spread to Rome, Carthage, and other cities around the Mediterranean Sea. A problem encountered with this early lime mortar was that it gradually dissolved when exposed to rainwater (Encyclopedia Britannica, 1984).

Roman concrete
The fame of Roman engineers as master builders is due in no small part to their use of lime cement mixed with broken tile, stone, volcanic ash, and water to form strong, long-lasting concrete structures. The Romans greatly improved the strength and durability of concrete and were the first to use it in significant amounts. The words "cement" and "concrete" come from the Latin words caementum, for pieces of rough uncut stone, and concretus, which means to grow together. Roman masons screened and washed sand and gravel (called "aggregate") in preparation for use in concrete. The practice of screening and washing sand and gravel is still necessary for making sound concrete.

Figure 1. Transamerica Building, San Francisco, California. Concrete products are pervasive, and it is hard to imagine our society without them. The graceful Transamerica Building in San Francisco is one example of the varied forms and functions of concrete design. At 853 ft high, it is the second tallest building in California. Photo by Don Dupras.

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Footnote:
1 Aggregate is a general term that refers to any hard inert material such as sand, gravel, smelter slag, or crushed rock. Strong and durable aggregate is of prime importance in cement products such as concrete, mortar, and plaster. These materials commonly contain more than 70 percent aggregate by volume.
In about 150 B.C., the Romans discovered that a glassy, fine-grained volcanic ash added to lime cement in place of sand made the concrete water-resistant and gave it superior strength. The best Roman cement was made with volcanic ash they called “pozzolana,” which was quarried near the town of Pozzuoli, Italy. The ash had been erupted from the volcano Mount Vesuvius (Hansen, 1982).

Roman pozzolan cement had the ability to harden under water. This water-resistant property is caused by silica in the volcanic ash chemically reacting with lime to form insoluble compounds in concrete. This superior cement enabled the Romans to construct resistant concrete marine facilities such as seawalls, piers, lighthouses, and breakwaters. The remains of these ancient structures can be seen today on the shores of the Mediterranean Sea (Encyclopedia Britannica, 1984). Today, cement of this type such as portland cement is termed “hydraulic cement.” Pozzolan is a common admixture used in modern concrete structures, and concrete made with such hydraulic cement can be placed under water through a hose called a “tremie.”

Roman engineers were the first to use lightweight concrete in building construction. Broken pumice, a lightweight porous volcanic glass, was used as aggregate when lightweight concrete was required. Lightweight pumice concrete improved wall insulation, reduced construction weight, and was better able to withstand frost action (Stapleton, 1981).

After 2,000 years, many examples of Roman concrete remain in place and illustrate the important contribution this material has made to modern civilization. Roman engineers constructed the world’s earliest and most enduring examples of concrete architecture. The Pantheon, Colosseum, Hadrian’s mausoleum, Roman baths, aqueducts, and Roman roads throughout Europe are monuments to the varied forms and functions of early concrete design. Concrete enabled the Romans to experiment with circular walls, vaulted ceilings, and domes; Roman concrete architecture still influences and inspires contemporary engineers.

The circular-domed Pantheon in Rome has survived virtually intact and is the most famous early concrete structure in the world. It was an architectural experiment and one of the first large concrete structures to incorporate lightweight aggregate concrete. The Pantheon was completed in 124 A.D. and dedicated as a religious temple. At the time, it was more than twice the size of any other domed building (Figure 2). Its 21-ft-thick circular wall is honeycombed with cast pozzolan concrete arches and sandwiched by marble veneer (Norwich, 1978; Mark, 1987).

Although the wall is an engineering feat in itself, the most interesting aspect of the Pantheon is its dome. The dome is 143 ft in diameter, 4 ft thick at the center, and incorporates nearly 5,000 yd³ of poured pozzolan concrete (Hansen, 1982). The base of the dome was made with normal sand and gravel aggregate for strength, because concrete strength is lost when lightweight aggregate is used. As the builders approached the top of the dome, they used lighter and lighter aggregate in the concrete until at the center, only pumice aggregate was used. The Pantheon is the only Roman building with its dome still intact (Stapleton, 1981).

The Roman Colosseum, a limestone, mortar, and concrete stadium, was completed in 80 A.D. and could accommodate 60,000 people. The word “colossal” is derived from the Latin word meaning huge. The Colosseum included miles of barrel-vaulted and groin-vaulted concrete passageways that provided smooth movement for the crowds. The foundation was built with 40-ft-deep concrete pilings.

Many other large Roman public works such as aqueducts, mausoleums, and sewer systems were constructed with cement mortar and concrete. One example of this type of construction is the extensive Cloaca Maxima sewer system beneath the streets of Rome. Another example is the graceful Roman aqueduct near Nimes, France, which was completed in 18 B.C. The portion of the 24-mi-long aqueduct that crosses the river, called the Pont du Gard, still stands and is 155 ft high. The top level supports a mortared water conduit 4 ft wide and 5 ft high (Stapleton, 1981).

The illustrous Roman road system that connected the empire had nearly 54,000 mi of highways and another 254,000 mi of connected roads. Engineers provided adequate drainage and carefully surveyed highway routes for directness between towns. Commonly, these highways were 4 ft thick and layered, with sand and gravel at the base, concrete in the middle, and stone blocks at the surface. The rigid roadbeds normally lasted 30 to 40 years without repairs. Several of these roads lasted for hundreds of years after the fall of the Roman Empire—even without repairs (Stapleton, 1981; Weisburd, 1988).

The technology of making high-quality, sound concrete declined after the fall of the Roman Empire. The low point of inferior concrete design in Europe occurred between the 9th century and the 11th century, when the practice of using sufficient heat to calcine limestone was abandoned. During the 12th and 13th centuries, proper calcining temperatures were again initiated, and the quality of cement gradually improved. By the end of the 1500’s, pozzolan materials were again used in concrete mixtures. Concrete development progressed very slowly from that period until the Industrial Revolution (Lewis, 1981).

By the 1700’s, engineers throughout Europe were experimenting with various natural cementitious materials that included limestone, limy mud, gypsum, pozzolan ash, oyster shells, diatomaceous earth, and chalk. Because the ingredients in these “natural cements” varied widely, and because procedures for making concrete were often haphazard, the quality of concrete structures made in the 1700’s was erratic.

Figure 2. The Pantheon, Rome, Italy. The entrance portico inscription, “M. AGGRIPPA. L. F. COS. TERTIVM. FECTI” (Latin for “Marcus Agrippa, son of Lucius and three times consul, built this”), refers to an earlier rectangular temple that was built on this site about 25 B.C. and later destroyed by fire. The domed Pantheon was added to the portico in 124 A.D. and dedicated to the seven major Roman gods. It is unique not only for its innovative concrete architecture but also because it is one of the very few buildings of Imperial Rome that have remained intact—a testament to solid concrete design. The large interior drum-shaped room has inlaid marble floors and is covered by a poured concrete dome 143 ft in diameter that was not exceeded in size until the mid-1800’s. The dome has a 30-ft-wide oculus or round opening in the top to illuminate the interior. The 21-ft-thick walls are not solid concrete but are honeycombed with concrete arches. The Pantheon is one of the first large concrete buildings and still serves as an architectural model for other domed buildings. This and following photos courtesy of the Portland Cement Association except as noted.
It should be noted that natural cements are still used, mainly in nonindustrial countries, and make fairly durable concrete structures. Natural cements have less durability, are less versatile, and harden faster than portland cement. However, some have remarkable compressive strength of 11,000 lb per in² (Draffin, 1943).

PORTLAND CEMENT
The Industrial Revolution in England caused a serious shortage of timber for the building trades. During that time, there was an intense demand for canals, factories, harbors, and other structures. Builders sought to reduce their dependence on wood structures by using increasing amounts of mortar, brick, and concrete.

In 1757, civil engineer John Smeaton was hired to design and build the Eddystone Lighthouse off the coast of Plymouth, England. After conducting several experiments to determine what cementing materials would set and remain stable under seawater, he chose a mixture of calcined argillaceous limestone from the Isle of Portland and pozzolan ash brought in from Italy. His studies showed that the best cement could be made from limestones that had the highest clay content. The concrete proved to be exceptional, and the Eddystone Lighthouse lasted for 126 years before it was replaced. Smeaton is said to have rediscovered the Roman pozzolan cement formula by examining an old Roman document (Skinner, 1976).

Joseph Aspdin
Nearly all concrete used today incorporates portland cement. The credited inventor of this exceptional cement was Joseph Aspdin, a bricklayer and mason from Leeds, England. After much experimentation, Aspdin developed the process of carefully proportioning limestone and clay collected from local quarries, pulverizing it, and heating the mixture on his kitchen stove. He then ground the compound into a fine powder. The resulting hydraulic cement made a very strong and durable concrete when mixed with the proper proportions of water and aggregate. Joseph Aspdin named it “portland cement” because the limestone he used was quarried on the nearby English Isle of Portland (Figures 3-5) (Legget and Karrow, 1983).

Aspdin took out a patent on his portland cement in 1824. Shortly thereafter, he built a small kiln that produced up to 6 tons of clinker after several days of heating (Figure 6). Aspdin later discovered that a higher calcining temperature produced a superior cement, and he secretly incorporated the heating process (Lewis, 1981). For a number of years, Aspdin’s portland cement process slowly expanded.

However, portland cement concrete proved to be so durable, versatile, and efficient that by the 1850’s, the process for making the cement was well established in England, Germany, and Belgium.

It is generally agreed that Joseph Aspdin was not the sole inventor of portland cement, because other English inventors were also working on similar cementing materials in the region during that time. In any event, within a month after pouring, portland cement concrete developed nearly twice the compressive strength of many other natural concretes then used.

Aspdin lived to see the first bulk use of portland cement as a masonry liner in a tunnel that went under the Thames River. Portland cement today is manufactured basically the same way as Aspdin’s patented process, but it is made with far greater precision and in far greater tonnages than he ever dreamed.

Figure 3. Drawing of Joseph Aspdin at his workshop. He patented his process of making artificial stone in 1824 and called it “portland cement.” Nearly all construction concrete used in the world today incorporates portland cement as its fundamental binding ingredient. Most portland cement used today is nearly the same as that discovered by Joseph Aspdin.

Figure 4. Aspdin’s original cement plant in Wakefield, England, around 1860. The first extensive use of cement was in the Thames Tunnel in 1828. The engineer in charge of the project insisted on using portland cement and faced strong opposition because it cost more than twice as much as other natural cements then available. The cement proved worthy, and in the 1860’s, nearly 70,000 tons of portland cement were used in the construction of the London sewer system. Aspdin’s son William tried to keep his father’s formula a secret by placing trays of copper sulfate in the kilns during the calcining process. The noticeable smell was intended to deceive competitors.

Figure 5. The famous limestone quarry on the Isle of Portland, south coast of England (around 1850). When Joseph Aspdin was experimenting with his cement concoctions, he had no efficient way of grinding the limestone. He found that the steel-rimmed wagons had sufficiently pulverized the limestone along the quarry road for his experiments. In 1825, while collecting crushed limestone samples along the main quarry road, he was arrested and fined for theft of public property.
U.S. portland cement

In an effort to expand their markets, European manufacturers began shipments of portland cement to the United States in 1868. To reduce freight costs, the cement was first shipped in wooden barrels\(^3\) as ship ballast. Portland cement proved to be so durable and versatile that engineers in the United States soon preferred it to other natural cements then in use, and shipments increased (Figure 7). The portland cement market in the U.S. quickly spread.

David Saylor had previously worked in the manufacture of natural cement concrete and felt that he too could make Portland cement (Figure 8). In 1871, he made the first portland cement in the United States at Coplay, Lehigh Valley, Pennsylvania. Saylor found that an argillaceous limestone\(^4\) in that valley contained the proper proportions of ingredients needed to make quality portland cement. Like Smeaton and Aspdin, Saylor systematically studied the physical properties of cement and concrete to improve it. His operation was a success, and his company prospered.

There was a strong demand for cement to accompany the rapid American industrialization during the 1870's and 1880's. Large engineering projects such as the Erie Canal, factories, sewer systems, and bridges fostered the spread and manufacture of portland cement in the United States.

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\(^3\) Cement is purchased and measured by weight because its volume changes due to compaction. The concrete industry still measures cement in barrels, a practice that dates back to the mid-1800's, when it was shipped in barrels. By definition, a barrel weighs 376 lb and contains four bags that are 94 lb each. A bag of cement is roughly 1 ft\(^3\).

\(^4\) Argillaceous limestone is common and contains as much as 50 percent clay minerals. This natural “cement rock,” as it is sometimes known, needs few additional materials to make good cement. An argillaceous limestone that would make a good portland cement would contain 50 to 65 percent lime, 10 to 20 percent silica, and 15 to 35 percent clay minerals, including alumina and iron oxide.
cylindrical kiln that slowly rotated. Crushed raw material could be continuously added at the top of the rotating kiln, calcined, and then removed. Early rotary kilns developed several problems that took years to remedy. Regardless of these problems, the invention of the rotary kiln is comparable to the development of the Bessemer process for making steel. Rotary kilns dramatically increased output, decreased costs, and improved the uniform quality of portland cement (Figure 9).

Thomas Alva Edison (Figure 10) was instrumental in improving the rotary kiln. He was convinced that mass-produced portland cement could provide affordable housing for everyone, and in 1898, he formed the Edison Portland Cement Company in Orange, New Jersey. In 1902, his company introduced the long rotary kiln. At 150 ft long and nearly 9 ft in diameter, the kiln ensured more nearly complete calcining, which resulted in a better cement. By 1905, the company was producing 715 tons of cement per day (Conot, 1979). In 1908, Edison realized his dream of an all-concrete, low-cost housing project and was one of the first to use tilt-up wall construction—a method in which concrete walls are poured into a mold at the job site, allowed to harden, and then raised into place (Figure 11).

In a nearby magnetite mining operation managed by Edison and his associates, there was a problem of crushing the hard iron ore for processing. So, in his characteristic manner, Edison invented the modern roll crusher, which, like many of his other inventions, is universally used today in the cement and other mining industries. The crusher had two mammoth, rapidly rotating iron cylinders equipped with iron studs, and it could grind six tons of very hard magnetite boulders in half a minute. He fondly called it his “Giant Rolls” (Conot, 1979).

The construction of the 41-mi-long Panama Canal took 32 years; the canal was finally completed in 1914. An estimated 5 million yd³ of concrete were used, and nearly 900 million yd³ of earth were excavated (Legget and Karrow, 1983). Canal construction did much to foster the improvement of concrete standards and equipment in the United States. One example is the refinement of the ready-mix truck commonly seen on highways today.

Modern production

As important as portland cement is to society, it is reassuring to know that the resources used to make it are abundant and occur worldwide. The basic raw materials for making modern portland cement include about 60 percent lime (CaO), 25 percent silica (SiO₂), 5 percent alumina (Al₂O₃), 4 percent gypsum (CaSO₄·2H₂O), 3 percent iron oxide (Fe₂O₃), and 3 percent...
magnesium oxide (MgO). Lime comes from limestone and marl. Silica and alumina are found in clays, shales, soils, and silica sand. Iron oxides occur in iron minerals, such as limonite, hematite, and siderite and in lateritic soils.

Magnesium oxide is a deleterious ingredient because in excessive amounts it expands over time and disintegrates concrete. However, all limestone contains small amounts of magnesium oxide, and it does not harm concrete if it is limited to amounts of less than 5 percent (Lea, 1970).

These raw cement materials are crushed, proportioned under exact chemical control, and ground to a sandy powder. The powder is then fed into a slightly inclined rotary kiln (some kilns are as long as 700 ft), and the load (or "charge") slowly moves toward the lower end, where it is first calcined and then gradually heated to a temperature of nearly 2,700 °F. This heating process normally takes approximately three to four hours. About 44 percent of the original load is lost as gases such as carbon dioxide and water vapor. When the charge reaches the "clinkering" temperature of 2,700 °F, it partially melts, changes composition, and emerges from the kiln as irregular, marble-sized balls called clinker (Table 1) (Figure 12). The clinker is mixed with 2 to 4 percent gypsum to regulate setting time and is then ground to a powder finer than flour. The resulting gray powder is Portland cement (Kosmatka and Panarese, 1988).

Over 99 percent of all concrete used today contains Portland cement. An estimated 1,700 Portland cement plants annually produce nearly a billion tons of cement worldwide (Huhta, 1988; Kosmatka and Panarese, 1988). California produces more Portland cement, concrete aggregate, and Portland cement concrete than any other state, and demand is expected to increase throughout the 1990s.

<table>
<thead>
<tr>
<th>Chemical name</th>
<th>Formula</th>
<th>Industry abbrev.</th>
<th>Percent</th>
<th>Function in concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricalcium silicate</td>
<td>3CaO·SiO₂</td>
<td>C₃S</td>
<td>55</td>
<td>Cementitious compound that adds strength, causes concrete to harden rapidly.</td>
</tr>
<tr>
<td>Dicalcium silicate</td>
<td>2CaO·SiO₂</td>
<td>C₂S</td>
<td>25</td>
<td>Cementitious compound that adds strength, causes concrete to harden slowly.</td>
</tr>
<tr>
<td>Tricalcium aluminate</td>
<td>3CaO·Al₂O₃</td>
<td>C₃A</td>
<td>10</td>
<td>An essential flux that promotes fusing of hydrous crystals, liberates a large amount of heat during the first few days.</td>
</tr>
<tr>
<td>Tetracalcium aluminoferrite</td>
<td>4CaO·Al₂O₃·Fe₂O₃</td>
<td>C₄AF</td>
<td>8</td>
<td>Reduces heat of hydration, assists in the formation of cement crystal growth.</td>
</tr>
</tbody>
</table>

* Clinker plus 4 percent ground gypsum (CaSO₄·2H₂O) constitutes Portland cement; cement plus aggregate and water produces concrete.

Figure 12. Grayish-black Portland cement clinker pellets with an average diameter of ½ in. The raw materials for Portland cement are heated to the clinkering temperature of approximately 2,700 °F. After the clinker is made in the rotary kiln, it is cooled, mixed with gypsum, and ground to the very fine powder known as Portland cement. Photo by David Parke.

PORTLAND CEMENT CONCRETE

Portland cement is rarely used by itself but must be mixed with aggregate to make concrete, grout, mortar, stucco, and the various other cement products used in the building industry. Portland cement mixed with fine aggregate (sand and gravel less than a quarter inch in diameter) is used to make cement plaster, mortar, and stucco. When it is mixed with sand and coarser aggregate (above a quarter of an inch in diameter), it makes concrete.

Nearly 99 percent of all structural concrete in the United States is made with Portland cement. Portland cement is the most expensive component of concrete, and most types of concrete contain only about 7 to 14 percent cement by volume. When Portland cement is mixed with the proper proportions of water (commonly 14 to 20 percent) and aggregate (commonly 60 to 80 percent by volume), the resulting concrete mix hardens—not by drying but by a process called hydration (Kosmatka and Panarese, 1988).

Curing

At the instant water is added to the concrete matrix, anhydrous compounds in the cement chemically react and begin to form new compounds. During this hydration process, the new complex compounds firmly bind the concrete matrix with criss-crossing, interlocking hydrous crystals (Hansen, 1982). The rate of hydration is affected by the composition and fineness of the cement powder, temperature, the amount of water present, and admixtures that can either accelerate or retard the hydration process.

The hydration reaction is so rapid that it is necessary to lengthen the curing time by adding materials. Gypsum is almost universally added to cement to retard the setting, although many other retarders are also available. For common concrete that is used in sidewalks, patios, and driveways, about 90 percent of the hydration process takes place within 28 days from the time it is poured. The hardening process, however, continues for months or years afterwards. Long curing periods are desirable to yield more nearly complete hydration of concrete. Theoretical tests indicate that common concrete that is precisely engineered and cured will continue to strengthen for 25 years or longer (Kosmatka and Panarese, 1988).

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Water must be available for the hydration process to continue. It is a common misconception that concrete hardens upon drying by evaporation. To avoid cracking and other problems, recently poured concrete projects should be kept moist for at least a week after they are placed. If poured concrete is not kept moist during the curing process, it can lose up to 50 percent of its designed strength. A common method of preventing the loss of moisture is to periodically spray the concrete with water or cover it with wet rugs or burlap bags. Another method used in large construction projects is to spray membrane-curing compounds on the fresh concrete; the membrane acts as a barrier to evaporation.

To make sound concrete, only that amount of water necessary for hydration is required. However, a concrete mix that contains only the amount of water necessary for hydration is stiff (or “lean,” as it is known in the trade) and is laborious to place. Because such a lean concrete is difficult to place and work, more water is commonly added to make the mix easier to pour and finish. The addition of more water than is required for hydration lowers the strength of the concrete (Waddell, 1974, 1985).

For example, an average machine-mixed concrete blend can withstand pressures of 3,000 lb per in² 28 days after it is placed. If extra water is added to the mix to make it easier to place and finish, the concrete strength may be only 1,500 lb per in² after 28 days. If the concrete is used to make a front yard mowing strip, the reduction in strength is not important. If, however, the concrete is used for a building foundation, the strength reduction may be serious. If too much water is added to the mix, there is not only a significant loss of strength but also the risk that the pieces of aggregate may separate from the matrix and the concrete will fail.

Heat is generated during the hydration process, and when large amounts of concrete are poured, as in dams or bridge abutments, the heat from the hydration is reduced or drawn off to avoid damaging the concrete. For large construction jobs (dams, bridge foundations, or freeway overpasses), specialty cements that produce less heat and take longer to cure are used (Kosmatka and Panarese, 1988).

**Placing**

Portland cement concrete for dams and large bridges is mixed near the construction site. For smaller jobs, it is brought to the construction site ready-mixed in agitator trucks. Ready-mix trucks, with their characteristic tilted, rotating, barrel-shaped mixers, deliver the concrete in readiness from a central plant called a “batch plant.” The truck operator then places the fresh concrete by means of a metal chute that folds out from the back of the truck. It is important to place concrete from the mixer to the form as rapidly as possible so that no initial setting occurs. The entire ready-mix operation from batch plant to placement is usually completed within 90 minutes.

When placing fresh concrete in difficult-to-reach areas, such as when constructing skyscrapers, concrete is pumped through a long tremie hose attached to a crane. Some concrete pump trucks can lift and place concrete above 500 vertical ft. For large jobs or when structural support is critical, the concrete is agitated after it is poured by portable vibrators to ensure that no void spaces remain in the corners and recesses of the form.

**Reinforced concrete**

Although sound concrete can withstand intense vertical pressure called “compressive strength,” its resistance to tensile stress (or pull-apart force) is relatively weak. In other words, a standing pillar of concrete that is 4 in. wide and 6 ft tall would be easy to break with a sideways hammer blow. To remedy this imperfection, engineers use reinforcing materials that have high tensile strength. The most common type of material used is steel rebar (rods). In addition to its high tensile strength, concrete reinforced with steel rebar will expand in the summer and contract in the winter at an even rate, with no damage to the concrete. Steel rebar is ribbed to improve its bond with concrete (Figure 13). In general, the thicker the reinforced concrete structure, the thicker the rebar used. Welded, high-strength wire meshes are used in the construction of road, floor, and flat-roof concrete slabs.

![Figure 13. Columnar section of rebar concrete taken from a building foundation.](image)

**Concrete failure**

Concrete failures are usually caused by faulty construction techniques rather than by flawed design. When a large concrete structure fails, engineers use a variety of forensic tools to determine what happened. High-frequency sound waves, for example, are commonly used to determine the structural strength of concrete. Because the speed of sound in concrete is known, the time it takes the sound wave to pass through concrete can be translated into feet and inches. Similarly, sound waves sent through concrete foundation footings, walls, or columns can be monitored for unusual patterns of deflection that indicate the presence of interior cracks, air pockets, or extraneous items. In one failed concrete structure, a lunch pail was found to have been inadvertently left behind when the concrete was poured (Allman, 1988).

To ensure that reinforcing steel rebar has been properly placed in concrete structures, portable X-ray machines and instruments that measure fluctuations in a magnetic field are used (Allman, 1988).
A common problem that is especially prevalent in marine structures is rebar corrosion hidden within the concrete. Engineers use portable instruments to measure the rebar corrosion by measuring the electric potential on the surface of the concrete. Sharp surges and variations of electric potential that differ from calibrated electric amounts of undamaged concrete indicate the amount of concealed corrosion.

CONCLUSION
Concrete is the most common building material in the world. It is a marvel of civilization that has been used for thousands of years and will remain a necessary building material for a long time to come. In the days of ancient Rome, the development of concrete was made by trial and error. In contrast, researchers today are aggressively using the scientific method to fully understand the myriad complex chemical reactions that take place to create lighter, stronger, and more durable concrete structures. The introduction of innovative types of concrete is changing the way architects and engineers design and build bridges and the many other concrete structures we rely upon and take for granted.

REFERENCES

NEW PUBLICATIONS RECEIVED IN LIBRARY

From time to time, we announce the receipt of new publications from outside sources that we think will be of interest to our readers. Copies of these publications are currently in the library of the Oregon Department of Geology and Mineral Industries, where they may be examined. Information about ordering and prices are listed below.

The Art of Geology, edited by Eldridge M. Moores, Department of Geology, University of California at Davis, and F. Michael Wahl, Geological Society of America. Published in 1988 as Special Paper 225 by the Geological Society of America, 3300 Penrose Place, P.O. Box 9141, Boulder, Colorado 80301. Hardcover, 9-in. by 12-in. format, 147 pages, full color throughout, with dust jacket, price $37.50 postpaid.

Designed to celebrate the 1988 Centennial of the Geological Society of America (GSA) and inspired by geologic photos submitted for the cover of GSA's monthly journal Geology, this handsome volume contains 250 scenic and geologic photographs arranged in 69 essays, each accompanied by a brief nontechnical text. Following a colorful rendition of the geologic time scale and an introduction discussing briefly the history of GSA, geologic time, geologic processes, and plate tectonics, the book opens with a startlingly beautiful series of photographs of slot canyons of the Colorado Plateau. Places such as Svatifikoss Waterfall in Iceland, Tambora Volcano in Indonesia, Teton National Park in Wyoming, Cordillera del Paine in Chile, the Brooks Range in Alaska, Rodadero in Peru, Arches National Park in Utah, Suez Rift in Egypt, and Central Park in New York City are subjects of photographic essays. The scale of pictures ranges from photomicrographs of peridotite from a South African diamond pipe to radar imagery of folds on the planet Venus. Geologic features such as thrust faults in Spain, unconformities in the Grand Canyon, ground-water erosion in Utah, and karst towers in China produce striking photographs.


All in all, this fascinating book is an appropriate way for GSA to celebrate its first 100 years—by sharing the visual wonders of geology with those of us who have not yet had the opportunity of seeing them first hand.


This is the last of the 20 correlation charts of the United States published as part of the COSUNA project by the American Association of Petroleum Geologists (AAPG) Research Committee in cooperation with the Committee on Stratigraphic Correlations. The charts are intended to show stratigraphic columns that provide fairly complete coverage of the geology of the United States. The North­west Correlation Chart contains sections for Oregon, Washington, and Idaho, including the Roseburg area, Cape Blanco area, Coos Bay area, Redwood (subsurface), Eugene area, central Coast Range, McMinnville-Sheridan area, Oregon City-Molalla area, Astoria area, Columbia County area, south flank of the Willapa Hills, Grays Harbor Basin, Centralia-Chehalis area, western Olympic Peninsula, northwest Olympic Peninsula, northeast Olympic Peninsula, Bremer-
DOGAMI releases first reports of 1989

State Map Advisory Council publishes annual report for 1988

The State Map Advisory Council for Oregon (SMAC) has released its annual report, a summary of its activities and accomplishments in 1988. The Council was established by Governor Neil Goldschmidt by Executive Order in 1987.

The 122-page report, which was produced under the chairmanship of State Deputy Geologist John D. Beaulieu and published by the Oregon Department of Geology and Mineral Industries (DOGAMI) as Open-File Report O-89-1, sells for $5.

The report provides summaries of over 20 meetings of the Council in its Executive Board, the Oregon Map Advisory Committee, the Oregon Geographic Information Systems Committee, and the Oregon Land Records Committee. Appendices describe the nature, mission, and goals of the State Map Advisory Council and its committees and present selected major plans, proposals, and budget priorities for 1989. The report concludes with membership lists of the various committees.

The Oregon SMAC is the lead governmental body in Oregon for mapping discussions. It consists of representatives from Federal and State agencies, local government, and private industry. Its purpose is to focus computerized mapping activities in Oregon and to further most efficient coordination of efforts.

Map for Mist Gas Field updated

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released an updated version of the Mist Gas Field map. The new map reflects all 1988 drilling activity in the field, including gas-storage and monitor-well activity. It has been published as DOGAMI Open-File Report O-89-2 and sells for $5.

The Mist Gas Field map defines a 141-mi² area within which special setback distances for gas wells are applied. The map is at a scale of 1:24,000 and measures approximately 40 x 50 in. It shows the Mist Gas Field divided into quarter sections and the setback lines for each section. Also shown on the map are the locations of all wells drilled, their total depth and year of completion, and all drilling locations permitted through 1988.

The official boundaries of the Mist Gas Field were approved by the DOGAMI Board of Governors in 1983, after a public hearing in which the previously accepted, unofficial field boundaries were revised.

New geologic quadrangle map for Owyhee region released

Geology and Mineral Resources Map of the Graveyard Point Quadrangle, Malheur County, Oregon, and Owyhee County, Idaho, by DOGAMI geologist Mark L. Fenn, has been released in DOGAMI's Geological Map Series as map GMS-54 and sells for $4.

The publication, resulting from an ongoing study of southeastern Oregon areas with a potential for mineral resources, was prepared in cooperation with the U.S. Geological Survey (USGS) and the Idaho Geological Survey and was partially funded by the CEGEOMAP program of the USGS.

The Graveyard Point 7½-minute quadrangle covers approximately 48 mi² east of Lake Owyhee and Owyhee Ridge and extends a little over a mile across the state line into Idaho. The new two-color map of the quadrangle (scale 1:24,000) identifies 19 Tertiary and Quaternary rock units, the oldest of which may date back to the late Oligocene (25 million years before the present). Geologic structure is described both on the map and in an accompanying cross section.

The approximately 28- by 40-in. map sheet also includes a discussion of the area’s mineral-resource potential and tables showing whole-rock and trace-element analyses of rock samples. A variety of valuable and potentially valuable mineral resources were found or indicated by the study, including bentonite clay, clinoptilolite zeolite, gold, mercury, semiprecious gemstones, building stone, and geothermal resources.

Earthquake hazard workshop to be held in Portland

The 1989 Workshop on Earthquake Hazards in the Puget Sound/Portland Area will be held March 28, 29, and 30, 1989, at the Portland Marriott Hotel in Portland, Oregon.

Sponsored by the Oregon Department of Geology and Mineral Industries (DOGAMI), the Oregon Department of Emergency Management, the Washington Department of Natural Resources, the Washington Department of Community Development, the Federal Emergency Management Agency, and the U.S. Geological Survey, the workshop has been designed to facilitate transfer of technical information from the geoscience community to engineers, planners, emergency responders, government officials, and members of the business community.

To improve the transfer of information, the first day of the workshop will have two parallel sessions: (1) a technical session in which geoscientists will present and discuss short papers, and (2) a nontechnical tutorial session in which basic technical issues will be explained and case histories illustrating major principles will be presented. The technical session will address topics such as faulting and seismicity of northwestern Oregon, southwestern Washington, and British Columbia; megathrust paleoseismicity; Cascadia margin deformation and megathrust ground motions; coastal terraces and subduction earthquakes; crustal and intraplate earthquake ground motions; liquefaction hazards; and tsunami modeling. The nontechnical session will cover such topics as Pacific Northwest plate tectonics and earthquake sources, basic seismology, special features of subduction zone earthquakes, ground response and failure, and building response and design. The first day will conclude with an evening poster session.

The second day of the workshop will provide brief technical summaries of the state of knowledge about earthquake hazards in the Portland and Puget Sound regions and an afternoon session on mitigation and policy, addressing such topics as existing earthquake hazard policies, response to changing earthquake hazards at the Trojan nuclear power plant, the Pacific Northwest view of earthquake hazards, and the Armenian earthquake of 1988.

The third day of the workshop will be a field trip to Netarts Bay, Oregon, to view evidence for Holocene and Pleistocene subsidence events presumably associated with large earthquakes. The trip will be led by Mark Darienzo, one of the authors of the Oregon Geology 1988 field trip guide to the same area (“Coastal Neotectonic Field Trip Guide for Netarts Bay, Oregon,” by C.D. Peterson, M.E. Darienzo, and M. Parker, Oregon Geology, v. 50, no. 9/10, p. 99–106).

Cost of registration for the workshop, which includes the first two days of the workshop and a luncheon on the second day, has been tentatively set at $35. The field trip will cost $15, which will cover transportation to Netarts Bay, lunch, and a field trip guide. For additional information, in Oregon, contact Ian Madin, phone (503) 229–5580. In Washington, contact Ray Lasmanis, phone (206) 459–6372, or Linda Nosen, phone (206) 481–4694.

To our readers

Oregon Geology changed from monthly to bimonthly publication after last year’s April issue, and eight issues were published in 1988. We marked the change by giving the last four issues double numbers and putting the names of two months on each issue.

This year, however, we are publishing a total of six issues, published in January, March, May, July, September, and November. These issues will all carry plain numbers, from one to six.

We value our subscribers, and we thank you for your continued support of Oregon Geology. Please do not hesitate to let us know of your wishes, comments, and news, so that we may serve you even better in the future.
DOGAMI installs display at Capitol

Staff members of the Oregon Department of Geology and Mineral Industries (DOGAMI) installed a new display on the main floor of the State Capitol in January 1989. Housed in the display case of the Oregon Council of Rock and Mineral Clubs near the gift shop, the display is built around the theme "Oregon's Hidden Wealth: Minerals."

The display, which will remain in place until mid-May, is designed to inform Oregonians about the importance of their mineral resources.

Faceters to meet in May

The 14th Annual Northwest Faceters Conference will be held starting Friday evening, May 26, and continuing on through the weekend of May 27 and 28, 1989, at the Lloyd Center Red Lion Inn in Portland. Sponsored by the Columbia-Willamette Faceters Guild, the meeting is designed to provide a forum where faceters and gemcutters can learn more about obtaining material and cutting it to best advantage. Included on the program will be presentations by Ron Geitgey, Oregon Department of Geology and Mineral Industries, on sunstones and other gemstones of Oregon; and by Ron Agee, the man who cut the world's largest topaz. A competition to decide who cut the best single stone will be held, and awards will be given at the Saturday noon banquet. Dealers will also be present at the conference, with equipment, uncut gemstone material, and jewelry findings.

Registration price for the conference, which will be $35, includes cost of the banquet. For additional information, contact Grover Sparkman, 3327 SE 50th Avenue, Portland, Oregon 97205, day phone (503) 775-6725, and evening phone, (503) 774-0048.

Fire Mountains of the West: The Cascade and Mono Lake Volcanoes, by Stephen L. Harris, Sacramento State University. Published in 1988 by Mountain Press Publishing Company, P.O. Box 2399, Missoula, Montana 59806. Paperback; 6-in. by 9-in. format; 389 pages; 148 illustrations including photographs, two-color maps, cross-sections, and schematic diagrams; price $15.95; available at local bookstores.

Fire Mountains of the West is a complete revision of Harris' popular book Fire and Ice. Designed for the non-technical reader, Fire Mountains of the West describes the major Cascade volcanoes and those in California's Mono-Mammoth Lake area, describing locations; geography; history—both human and geologic; hazards; and ways to approach and explore each particular area. The theory of plate tectonics, categories of volcanoes, types of magma, evolution of the Cascades, and glaciation are topics that are presented in simple terms with numerous easy-to-understand illustrations and appropriate photographs.

Although not designed to be used as a field-trip guide, this book provides rich details that will enhance anyone's appreciation of a specific volcano, even though he or she has visited it before. Because the book is nontechnical in style, Harris has not had to encumber his prose with the numerous citations that most technical papers require, making Fire Mountains of the West much easier to read and enjoy. He is careful, however, to cite and thank the people whose work have made this book possible, and he includes a bibliography for each chapter. Also included are a glossary and index.

For people who want to learn more about the Cascade volcanoes—their origins, histories, and futures—this book is highly recommended.
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Separate price lists for open-file reports, geothermal energy studies, tour guides, recreational gold mining information, and non-Departmental maps and reports will be mailed upon request. The Department also sells Oregon topographic maps published by the U.S. Geological Survey.

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