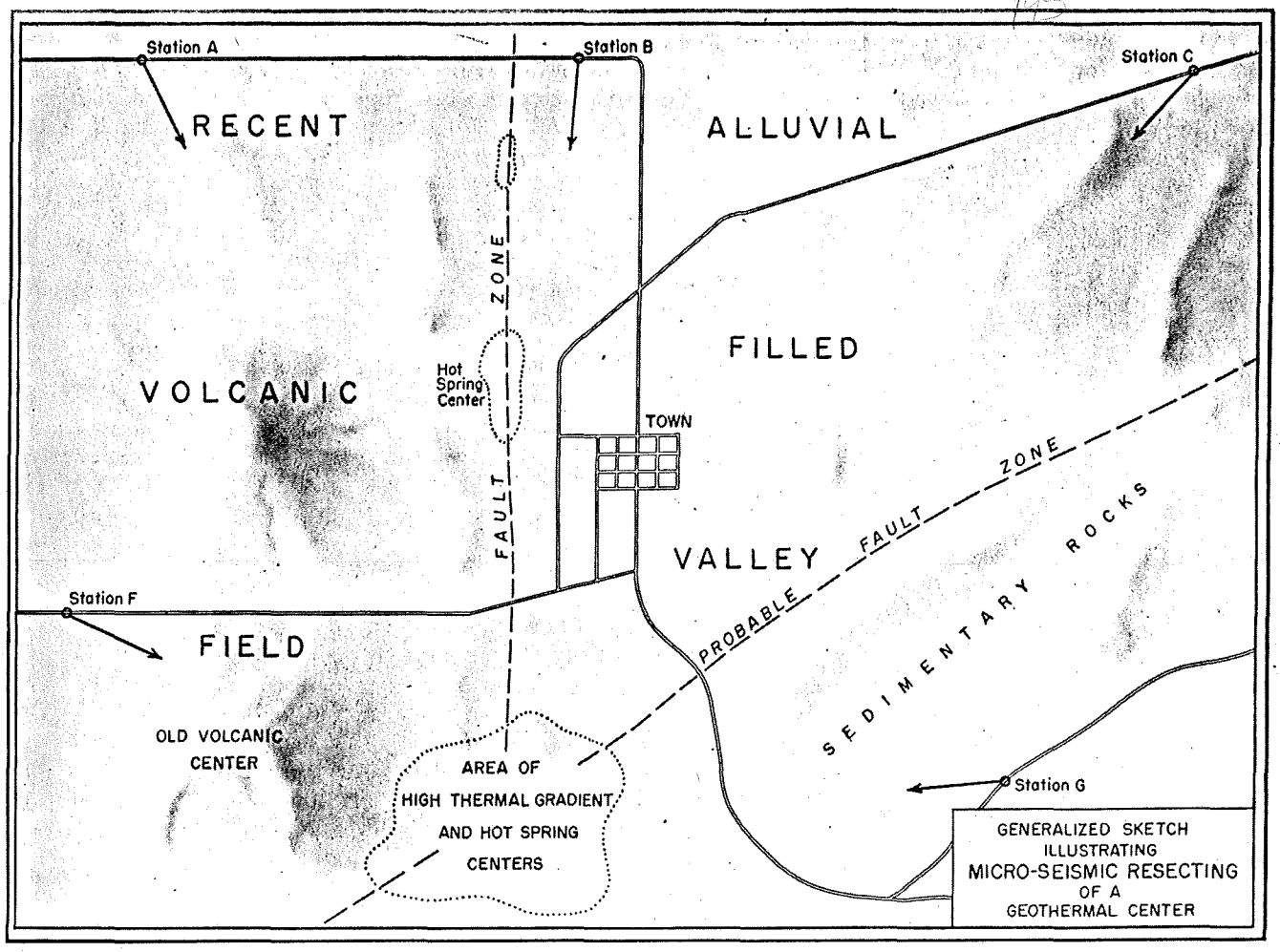

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Exploration in Progress For Geothermal Drilling Targets

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WIDESPREAD exploration is in progress throughout the western United States for promising geothermal reservoirs containing dry steam or thermal waters with highly elevated temperatures. The Rocky Mountain region from the thermal centers of north-central Montana to the southern part of the Rio Grande trench in New Mexico; eastern Oregon and Washington; the Snake River trench; the Basin and Range region; the eastern Fringe of the Sierras; the Cascades and the Coast Ranges of California—all are being evaluated with care. Both major oil and mining companies and independent geothermal exploration groups are involved. Favorable private land is largely taken up and Federal and State lands are being acquired under lease agreements. Active drilling programs are scheduled or are under way in many parts of the 11 western states.

Exploration for geothermal reservoirs is based on the search for thermal centers with high heat flow from an active or cooling igneous body located at reasonably shallow depths. There must be widespread permeability in the overlying reservoir rocks. Trap rocks above the cracked reservoir rocks add to the effectiveness of the reservoir containing dry steam or high temperature thermal waters. There must be inflow of meteoric water to replace losses in the system in order to assure continuity of production. Also there must be evidence of continuous micro-earthquakes which serve to keep the steam and water filled fractures open and freely circulating; otherwise silica, gypsum, carbonates or other alteration products tend to seal off the openings.

Data on areas which have hot spring, fumerolic activity and anomalous thermal gradients are generally

available through government sources. Regional geology maps point to areas of recent igneous activity and volcanism and major fault systems. Third dimension correlation of volcanic and sedimentary stratigraphy also is a vital aspect in establishing geothermal targets at depth. Once favorable targets have been established, mobile truck-mounted micro-seismic equipment may be utilized to resect on targets from various locations five to ten miles distant to see if the potential reservoirs are being kept open by micro-earthquake activity.

Some of the most favorable sites for geothermal reservoirs are along the Rio Grande and Snake River trenches where there are thick volcanic piles underlain by cooling igneous bodies, and which are cut by major, deep-seated faults with strong, associated fracture systems into which meteoric waters have ready access. Other targets are the cracked head zones of shallow igneous stacks of the Basin and Range region which have high residual heat flow. Still another is the deep-seated Sierra Nevada fault zone and similar fault zones to the east in Nevada which tap heat sources at depth and along which large volumes of meteoric waters circulate. The extensive hot springs at Steamboat Springs, located along the Sierra Nevada fault zone between Reno and Carson City, Nev., represent this type of circulation system. Geothermal reservoirs may occur where local trap conditions occur within and adjacent to these fault zones.

An example of the fault zone type of reservoir is at Thermopolis, Wyo., where hot springs occur along a major, deep-seated, east-west trending shear zone. Some 18,000,000 gallons of hot waters flow from the main spring each day and several nearby wells flow at a rate of 1,000,000 gallons a day. This flow reflects the inflow of large volumes of cold, meteoric waters from the Madison limestone and other permeable strata from the up-dip recharge area to the south along the north flank of the Owl Creek Mountains. Drilling deep into the fractured Precambrian basement adjacent to this fault zone may yield waters at or approaching steam level. A geothermal resevoir may exist under trap conditions within highly cracked Precambrian rocks well below the overlying, highly permeable Paleozic strata.