



## **INTRODUCTION**

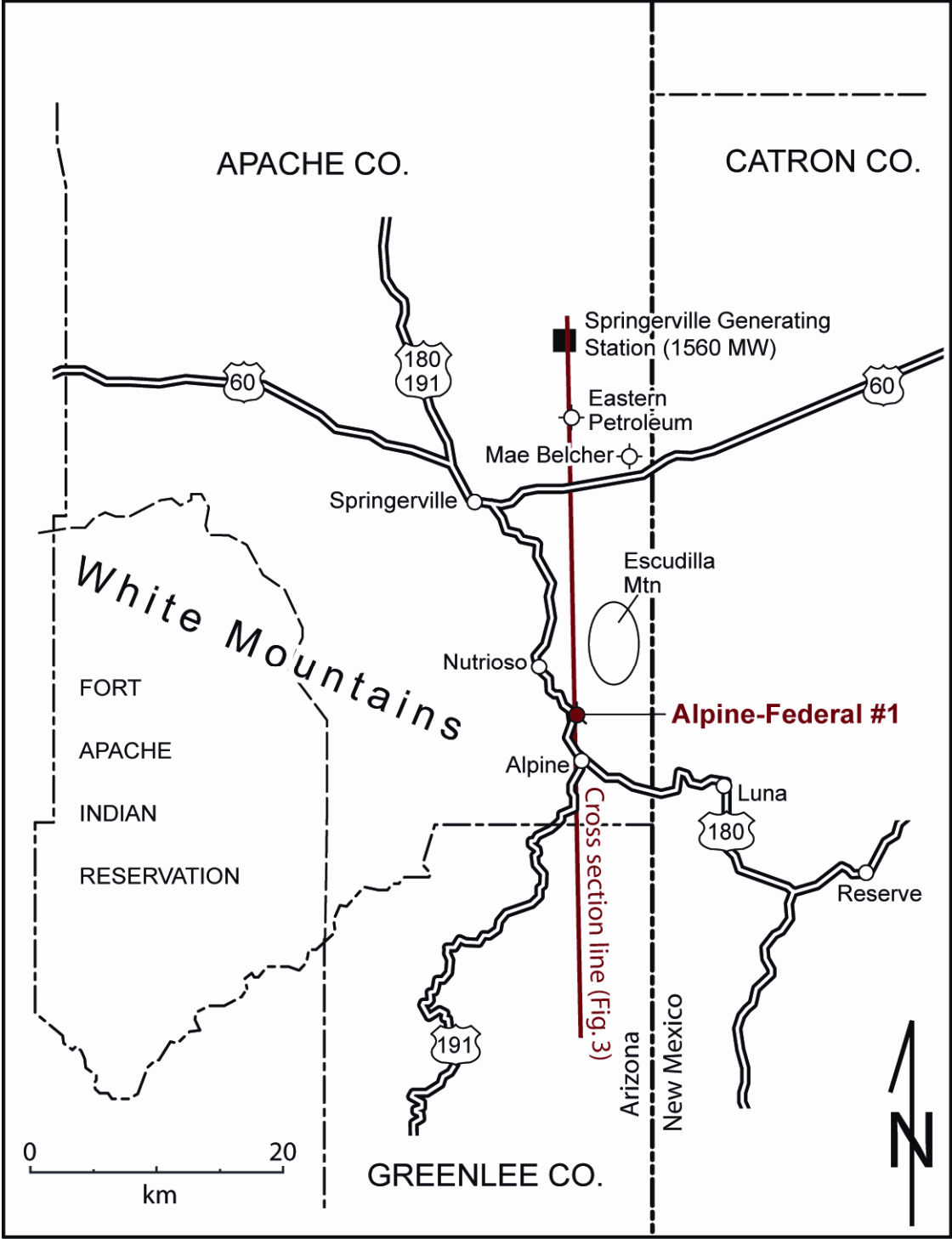
This open-file report describes the carbon-sequestration potential at the site of the 1 Alpine-Federal geothermal test drill hole, which is located south of Springerville in central eastern Arizona near the New Mexico border. A previous report, Arizona Geological Survey (AZGS) Open-File Report OFR 94-1, version 2.0, describes the subsurface geology encountered in the 1 Alpine-Federal well in much more detail than this new report.

The 1 Alpine-Federal geothermal test, at an elevation of 8,556 ft in eastern Arizona, was drilled by the Arizona Department of Commerce and U.S. Department of Energy to obtain information about the hot-dry-rock potential of Precambrian rocks in the Alpine-Nutriosio area, a region of extensive Quaternary basaltic volcanism in southern Apache County. The hole reached total depth of 4,505 ft (1373 m) in August 1993. Temperature measurements were taken through October 1993 when final temperature, gamma ray, and neutron logs were run. Details on the temperature gradients, geothermal potential, and geology encountered in the 1 Alpine-Federal are presented in AZGS Contributed Reports CR-94-D, CR-94-E, and CR-94-F (Witcher, J.C., 1994; Witcher, J.C., et. al. 1994; and Witcher, J.C., Hahman, W.R., and Swanberg, C.A., 1994a), and in New Mexico Geological Society Guidebook, 45th Field Conference (Witcher, J.C., Hahman, W.R., and Swanberg, C.A., 1994b).

The well is located just east of U.S. Highway 180/191 (old U.S. Highway 180/666) at the divide between Alpine and Nutriosio, in sec. 23, T. 6 N., R. 30 E., in the Apache-Sitgreaves National Forest (Fig. 1). The town of Alpine is about 6 miles south of the wellsite and the Arizona-New Mexico state line is about 6 miles east. The basaltic Springerville volcanic field is just north of the wellsite (Crumpler et al., 1994). Although volcanic rocks of middle Miocene to Oligocene age are widespread in the region (Cather and Johnson, 1984; Potochnik, 1989; Richard et al., 2000), erosion has removed them from the main valleys between Alpine and Nutriosio. As a result, the 1 Alpine-Federal was spudded in sedimentary strata of Oligocene to Eocene age (Richard et al., 2000). These sedimentary strata are exposed in road cuts along the highway and consist of light-colored, fine-grained clastic rocks with minor conglomerates. The White Mountains, formed of volcanic rocks, are to the west, Escudilla Mountain (capped by volcanic rocks) is north, the Datil volcanic field is east in west-central New Mexico, and the Mogollon Rim (also capped by volcanic rocks) is to the south.

## **STRATIGRAPHY IN THE ALPINE-FEDERAL HOLE**

The 1 Alpine-Federal penetrated Tertiary, Cretaceous, and Permian rocks (Fig. 2). Wellsite geologists reported Tertiary Datil Formation from the surface to 1,093 ft), Eocene Baca Formation at 1,093 ft (2,046 ft thick), Tertiary redbeds at 3,139 ft (121 ft thick), Cretaceous strata at 3,260 ft (109 ft thick), Permian San Andres Limestone at 3,369 ft (67 ft thick), Permian Glorieta Sandstone at 3,436 ft (203 ft thick), a mafic dike at 3,639 ft (drilled thickness of 112 ft), and Permian Yeso Formation, which is cut by two mafic dikes, at 3,751 ft (604 ft thick).



**Figure 1.** White Mountains area of east-central Arizona

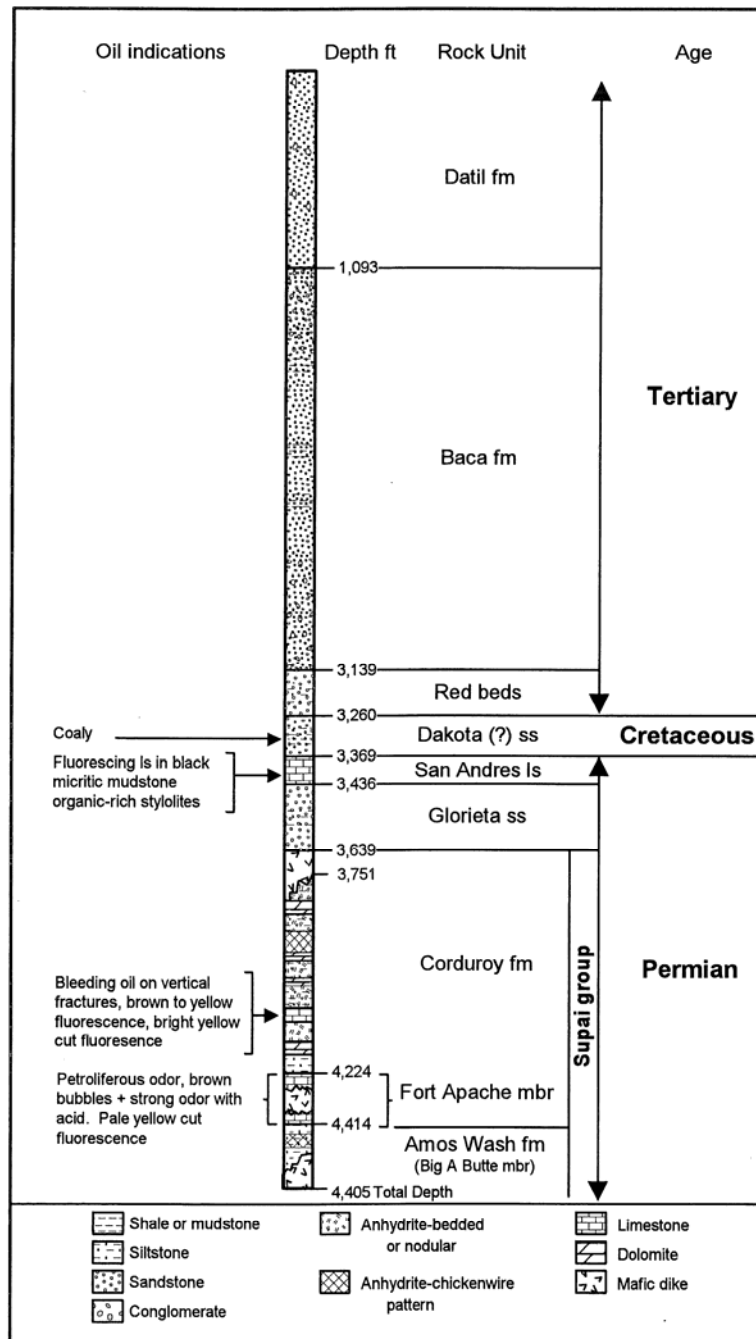


Figure 2. Rock units penetrated in 1 Alpine-Federal

## PENNSYLVANIAN

Although the 1 Alpine-Federal was not drilled deeply enough to encounter Pennsylvanian strata, mapping by Wrucke (1961, Fig. 2) suggests their presence beneath "Supai" at this location. He reported two large blocks of probable Pennsylvanian Naco limestone at an elevation of 8,600 ft on

the northeast flank of Escudilla Mountain (about 6.5 miles northeast of the 1 Alpine-Federal, see Fig. 1). He surmised that ascending magma carried these large blocks of Naco(?) limestone to the surface from their more extensive presence at depth (Wruccke, 1961, p. 24-25).

The northeasterly extent of Pennsylvanian rocks onlapping the southwestern edge of the Defiance Positive is constrained by two wells drilled north of Escudilla Mountain (Fig. 1). The Eastern Petroleum 1-A Coyote Creek in sec. 27, T. 10 N., R. 30 E., about 23 miles north of the 1 Alpine-Federal, penetrated Permian Supai Group over Precambrian granite at an elevation of 4,628 ft (Fig. 3). The Mae Belcher 1 State in sec. 20, T. 9 N., R. 31 E., about 18 miles north of the Alpine hole, penetrated Supai Group over Precambrian granite at an elevation of about 4,422 ft.

Wruccke's (1961) recognition of displaced Naco(?) limestone on Escudilla Mountain suggests that an edgeline of onlapping Pennsylvanian rocks exists between the 1 Alpine-Federal and the Mae Belcher and Eastern Petroleum wells. These rocks may be 750 ft thick at the 1 Alpine-Federal location (Kottlowski, 1959, fig. 1; Kottlowski and Havenor, 1962, p. 78; Kottlowski, 1965, fig. 6).

### **PRE-PENNSYLVANIAN STRATIGRAPHY**

Regional isopach mapping suggests that 165 ft (Armstrong et al., 1980, fig. 1) to 230 ft (Beus, 1989, fig. 2) of Mississippian strata and 150 ft of Devonian strata (Beus, 1980, fig. 2) could be present at the 1 Alpine-Federal location. Precambrian rocks at the 1 Alpine-Federal location may thus be as deep as 6,570 ft at an elevation of 1,985 ft, 2,400 ft structurally lower than the Precambrian surface at the Mae Belcher well. This buried paleogeographic Precambrian surface is the unexplored southwest edge of the Defiance Positive, which trends southeasterly through this region and extends at least 60 miles in a northwesterly direction (Peirce, 1979, fig. 1). Lindgren (1905) described a relatively complete section of lower Paleozoic strata at Morenci, which is about 60 miles south of the Alpine-Federal location, including about 200 ft of widely distributed quartzose sandstone of Cambrian age, as well as Ordovician carbonates. The basal Cambrian sandstone unit could extend northward into the vicinity of the Alpine-Federal location where it could serve as potential geologic reservoir for sequestering CO<sub>2</sub>.

### **IMPLICATIONS FOR CARBON DIOXIDE SEQUESTRATION**

Figure 3 shows the basic stratigraphy along a north-south profile through the 1 Alpine-Federal well. This cross section includes a profile of the approximate 1 km (3,280 ft) depth level as a guide to pressure conditions for CO<sub>2</sub> sequestration. It is apparent from the profile that all Paleozoic strata are below this depth at and near the well site. Considering that Paleozoic strata in Arizona typically contain several units of porous and permeable sandstone, and that the 1,560 megawatt, coal-fired Springerville Generating Station is in close proximity, the Paleozoic strata seem a likely target for CO<sub>2</sub> sequestration of CO<sub>2</sub> produced by the power plant. Before this is seriously considered, the 1 Alpine-Federal well could be re-entered and core removed for the undrilled remaining part of the Paleozoic section. Studies of core-sample permeability and porosity would allow evaluation of the favorability of this site, and of the buried Paleozoic strata in the region, for CO<sub>2</sub> sequestration.

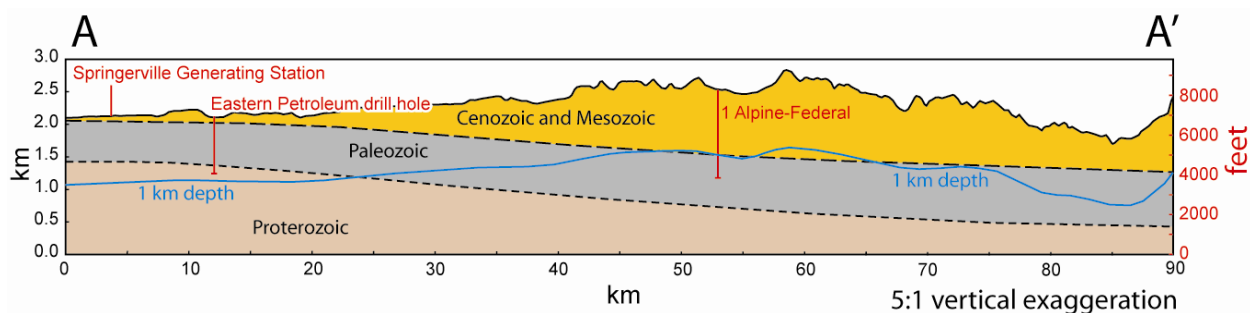


Figure 3. Cross section through the 1 Alpine-Federal drill hole. See Figure 1 for location.

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