U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

CORE LITHOLOGY
STATE OF HAWAII
SCIENTIFIC OBSERVATION HOLE 4
KILAUEA VOLCANO, HAWAII

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Open-File Report 92-586

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INTRODUCTION

The Scientific Observation Hole (SOH) program is sponsored by the State of Hawaii to drill and core research holes deep into Kilauea's East Rift Zone. This report consists of complete lithologic and temperature logs of the 6,565 ft of core from a 2,001-m-deep well recovered from SOH 4, located 8 km southwest of the town of Pahoa at an elevation of 366 m (1,200 feet) above sea level (asl; Fig. 1). This document synthesizes several types of information, and its purpose is to serve as a catalog and reference of the drill core. The original core log sheets, which are the basis of this document was derived are located at the University of Hawaii at Manoa.

Continuous core of this nature and depth is unprecedented in the Hawaiian Islands and provides an unequalled stratigraphic record of the physical and chemical development of the volcano. In addition, the cores provide samples on which to conduct physical property and chemical studies that will impact our basic understanding of volcanic island development and constrain future geologic and geophysical models.

LITHOLOGIC SUMMARY

A total of 1,463 units are identified in the 2,001 m of core from SOH 4, stored in 691 boxes. Units include a'a and pahoehoe flows, dikes, ash, carbonates, pillow lava, sand, hyaloclastites and volcaniclastite. Volcaniclastites are fine-grained subaqueously deposited volcanics. Specific characteristics used to distinguish unit types are presented in Figure 2. The breakdown by unit type in percent is as follows:

UNIT	PERCENT OF CORE
Dike	33.2%
Pahoehoe	35.2
A'a	21.7
Ash	1.1
Pillow lavas and Hyaloclastites	7.6*
Carbonates	1.03
Sand	0.17

* includes Volcaniclastics

FLOWS: Subaerial lava flows comprise 58% of the core and subaqueous flows 7% (including pillows, hyaloclastite, and volcaniclastics). The deepest subaerial flow occurs at a depth of 1,402 m (4,597 ft) below sea level (bsl). The transition from subaerial to subaqueous emplacement extends over 162 meters, starting with the shallowest subaqueous unit at 1,329 m (4,357 ft) bsl to the last carbonate at 1,461 m (4,790 ft) bsl.

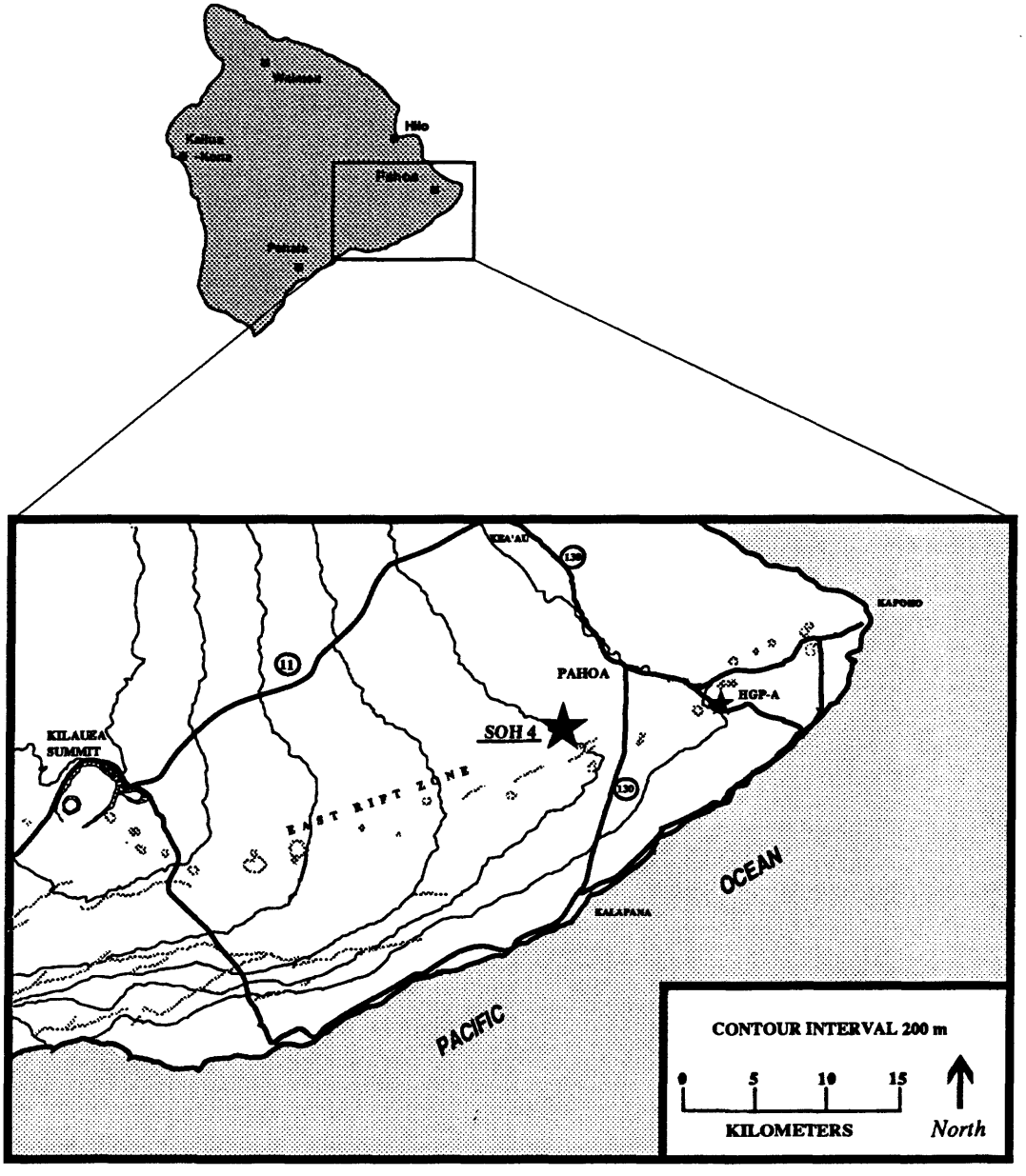
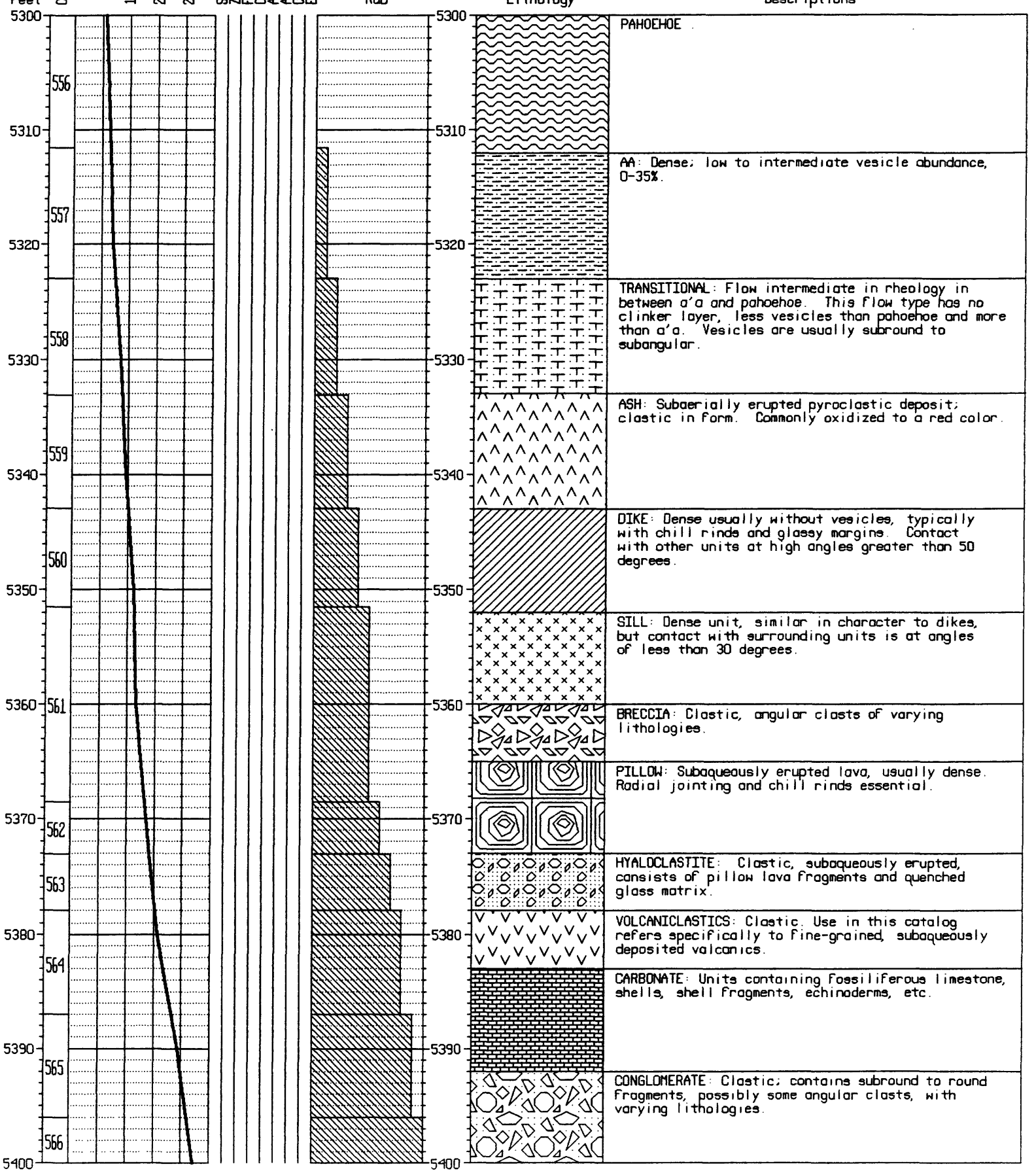


Figure 1: Site location map for SOH 4.

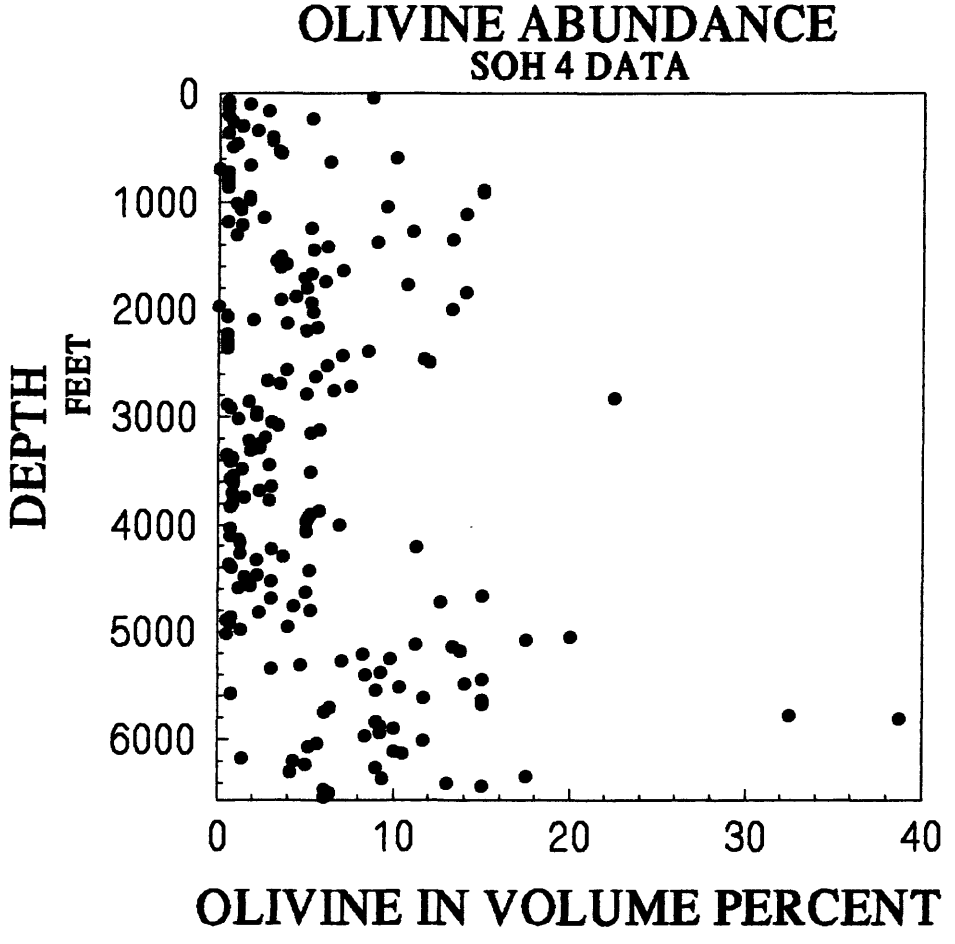
Figure 2 Graphic depiction of unit type and their characteristics.

LOG #49

Scientific Observation Hole
Site 4 Elevation 1200 ft a.s.l.

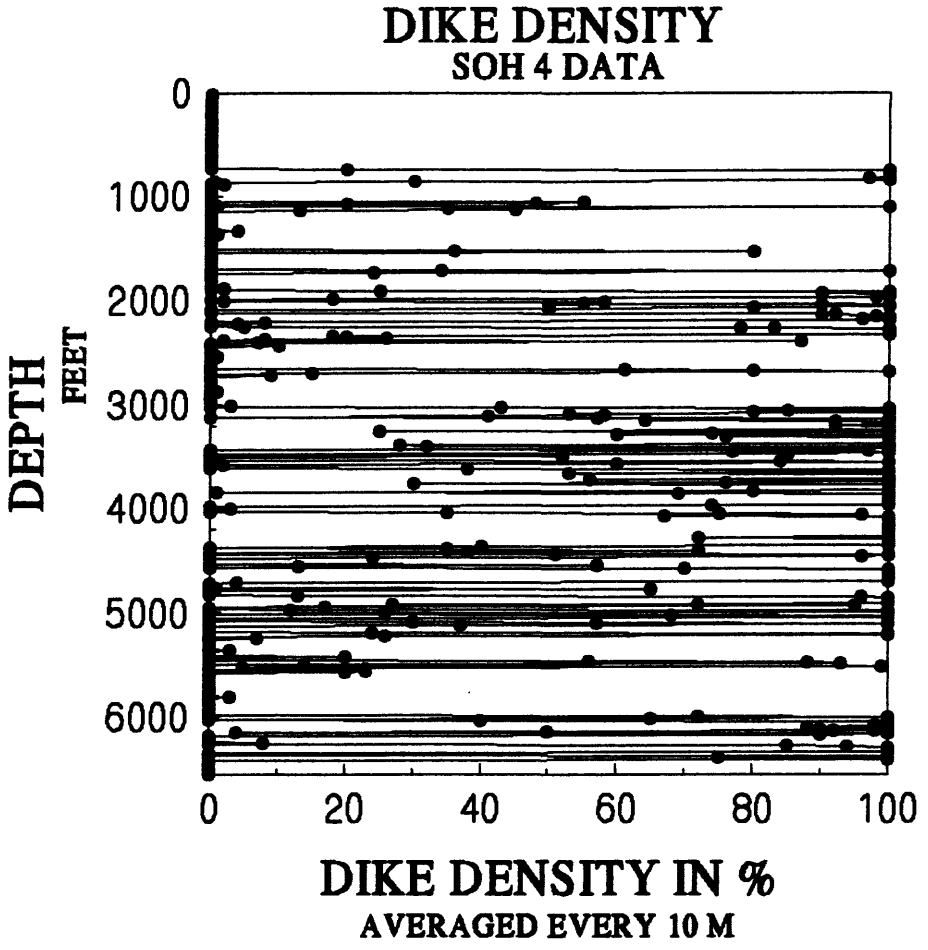


A general observation is that olivine phyric flows are more common at greater depths (Fig. 3).



ASH: A total of 19 Ash units, generally thin (<15 cm), are randomly distributed in the vertical section.

DIKES: Regions marked by frequent dikes, averaging 80% and greater dike rock per 30 m of core occur in the interval between 915 and 1,525 m (3,000-5,000 ft) depth bsl (Fig. 4). The presence of this high intensity of dikes versus flow units comes as a surprise, because the sheeted dike complex and region of current dike emplacement is at the 3,000-4,000-m depth. Dikes have chill margins (glassy contacts) that cross-cut the sub-horizontal flow units and therefore are younger than the units with which they are in contact. A thick (30 m, 98 ft) sill occurs at a depth of 135 m (443 ft) asl.



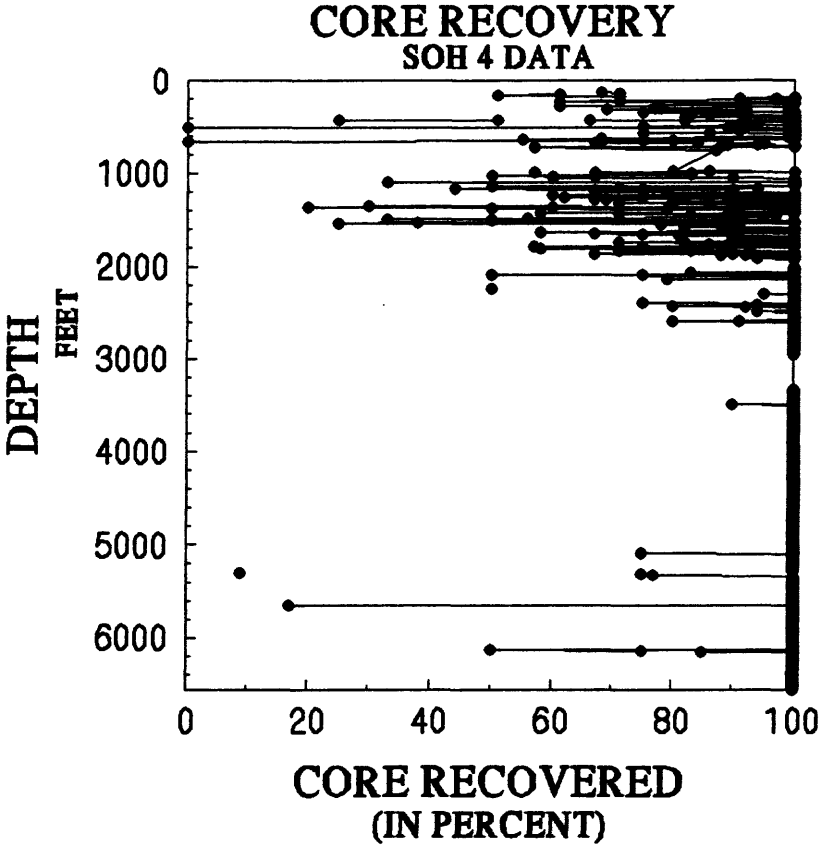
CARBONATES: Marine carbonates in the form of breccias, fossiliferous limestone and conglomerates were found at depths of 1,337-1,491 m (4,120-4,889 ft) bsl. The presence of shallow water foraminifera associated with the deposits suggest that this material formed in a lagoon or beach environment (pers. comm. J. Resig, 1990). The presence of shallow-water carbonates may be interpreted in several different ways, e.g., (1) Kilauea has subsided by 4,889 ft (1,491 m) and is much older than previously thought; (2) faulting has occurred and has displaced the old shoreline; and (3) the deposits represent the contact between Mauna Loa and Kilauea along an old Mauna Loa shoreline.

Using current subsidence rates of 2.4 mm/yr (Moore and Thomas, 1988) would yield ages of 557,083 to 621,250 years B.P. An alternative viewpoint is that the subsidence rates are too modest and that the sinking of the island has occurred at greater rates to arrive at the currently accepted age of Kilauea at approximately 250,000 to 400,000 years.

LOGGING SPECIFICS

The average core recovery rate for the entire SOH 4 drill hole is 93.6% (Fig. 5). Figure 2 is a sample core log illustrating the symbols used to depict different lithologies and descriptive terminology for the unit types. All graphical

representations of data presented in this reference are depicted for the entire box. For example, the graphic depiction of lithology is based on the dominate lithologic type, even though more than one type of unit may appear in a box. Secondary mineralogy bars reflect the presence of the mineral, but not the unit in which they occur. In all cases, the written core descriptions have additional detail on unit types and the occurrence of secondary minerals. Finally, all depths are reported in feet.



RQD, Rock Quality Data, was adapted from engineering and indicates the degree to which the core is fractured; higher values mean more competent or intact core. The scale is in percent, 0-100, and measurements begin at 280-ft depth (281 m asl). RQD is averaged for the entire box of core.

The third set of columns depicts the presence or absence of secondary minerals. With the exception of smectite-chlorite field, the secondary minerals usually represent <1% of the core. Smectite-chlorite is used to represent any type of clay mineral. Zeolites are also not discriminated on the bar graphs. When these secondary minerals have been specifically identified, their name appears in the core description section of the log. In most cases, the mineral identifications made in the field should be

considered preliminary until confirmed by X-ray diffraction or by other methods.

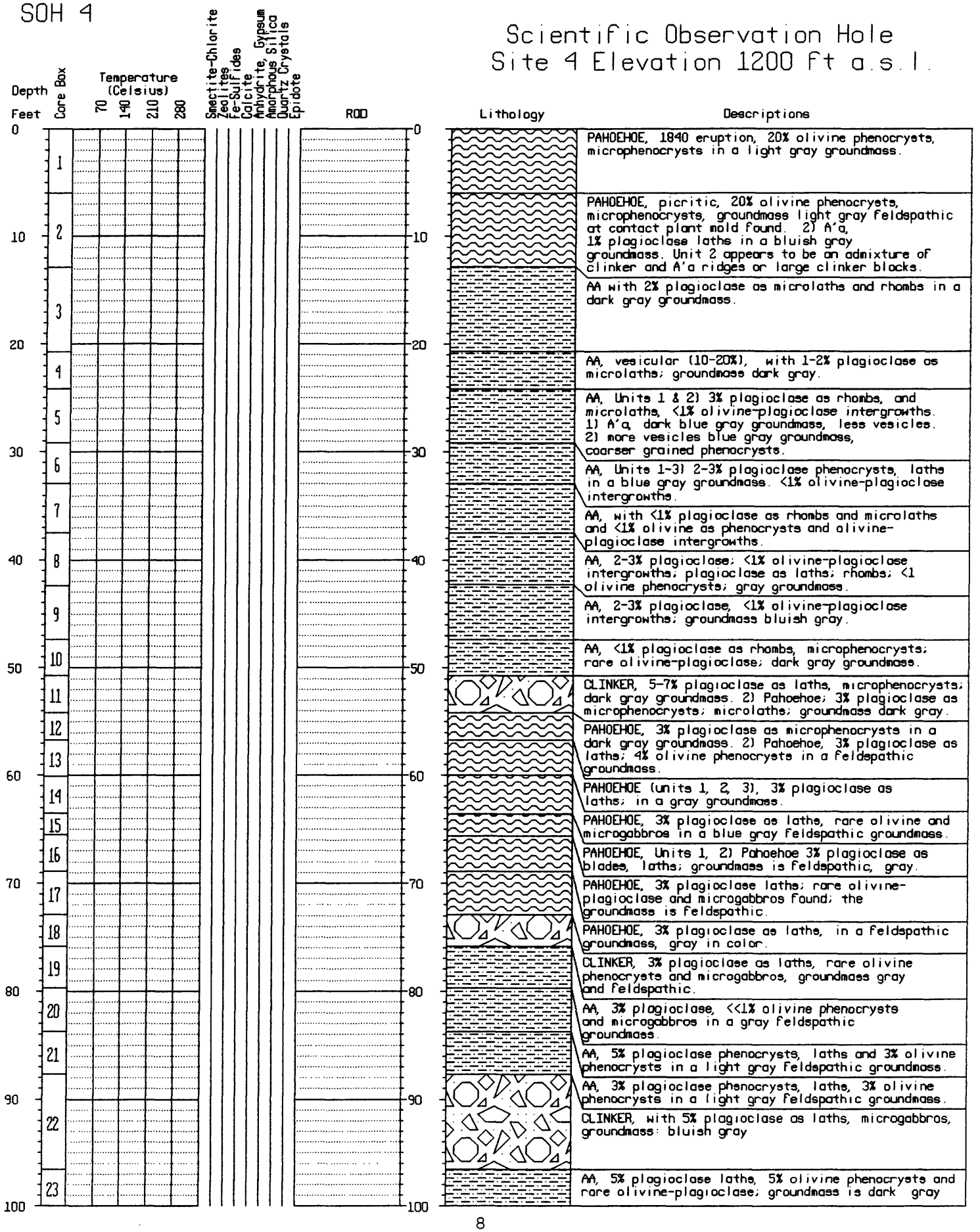
Temperature data were taken from Termacal Engineering survey of SOH 4 on May 22, 1990 (pers. comm. D. Thomas, 1990). Data were collected starting at the 335.5 m asl (100-ft depth, from surface) down to 1,616.5 m bsl (6,500-ft depth).

ACKNOWLEDGMENTS

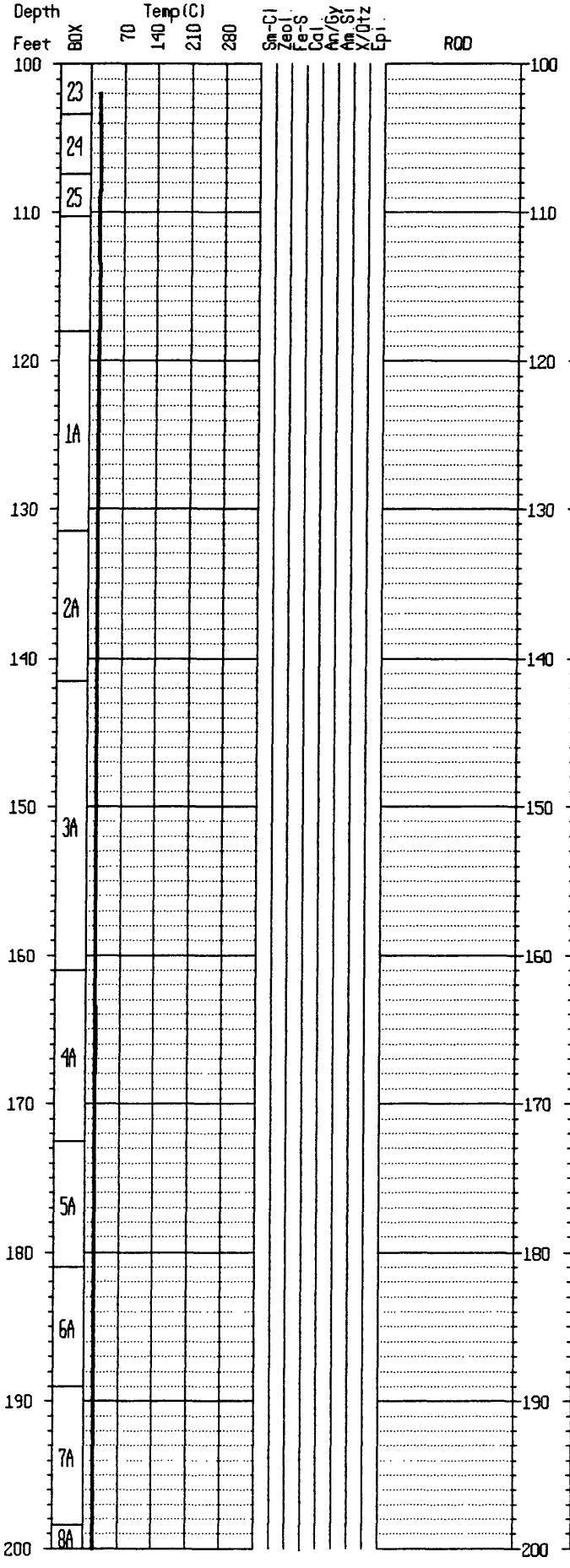
The data presented here was obtained while I worked for the Hawaii Natural Energy Institute. I would like to thank Dr. Don Thomas for allowing me the opportunity to work on such an exciting project. Dr. Martha Sykes and Dr. Terry Keith for providing secondary mineral XRD information and identification. Finally, I would like to acknowledge James P. Reed of Rockware for setting up the output format and for instructing me on the software usage.

SOH 4

Scientific Observation Hole
Site 4 Elevation 1200 ft a.s.l.

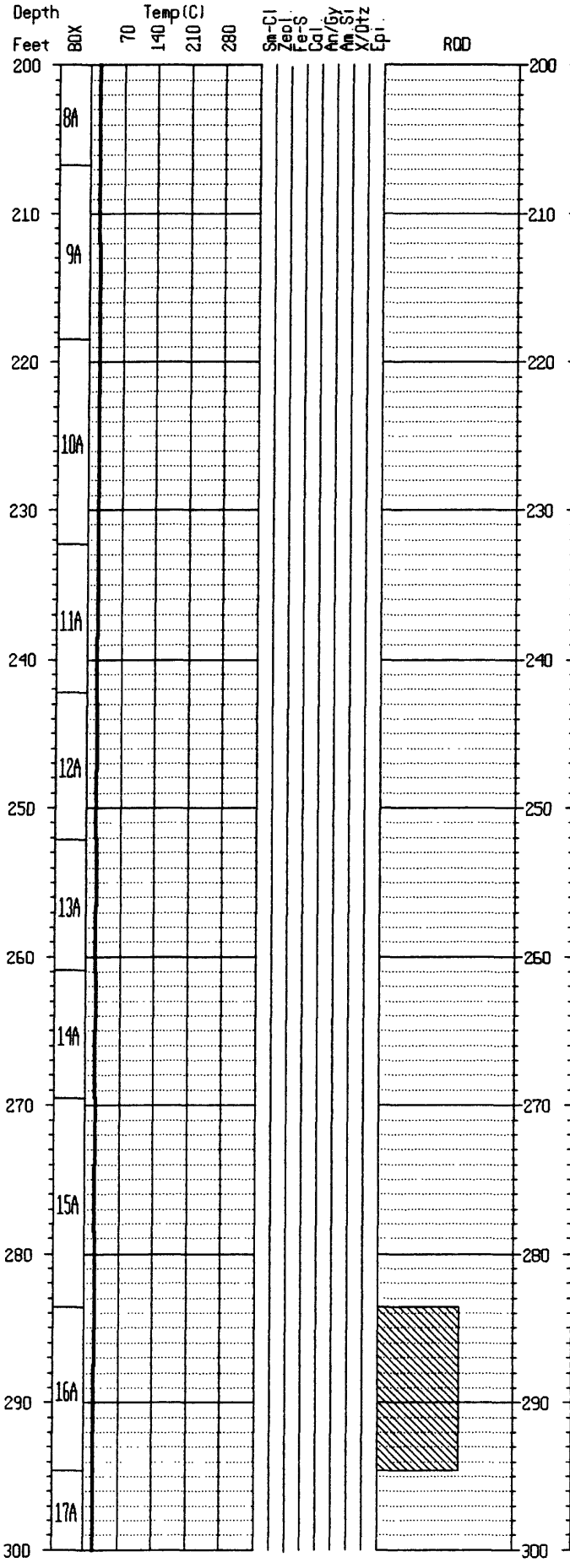


CATALOG OF SOH 4 CORE



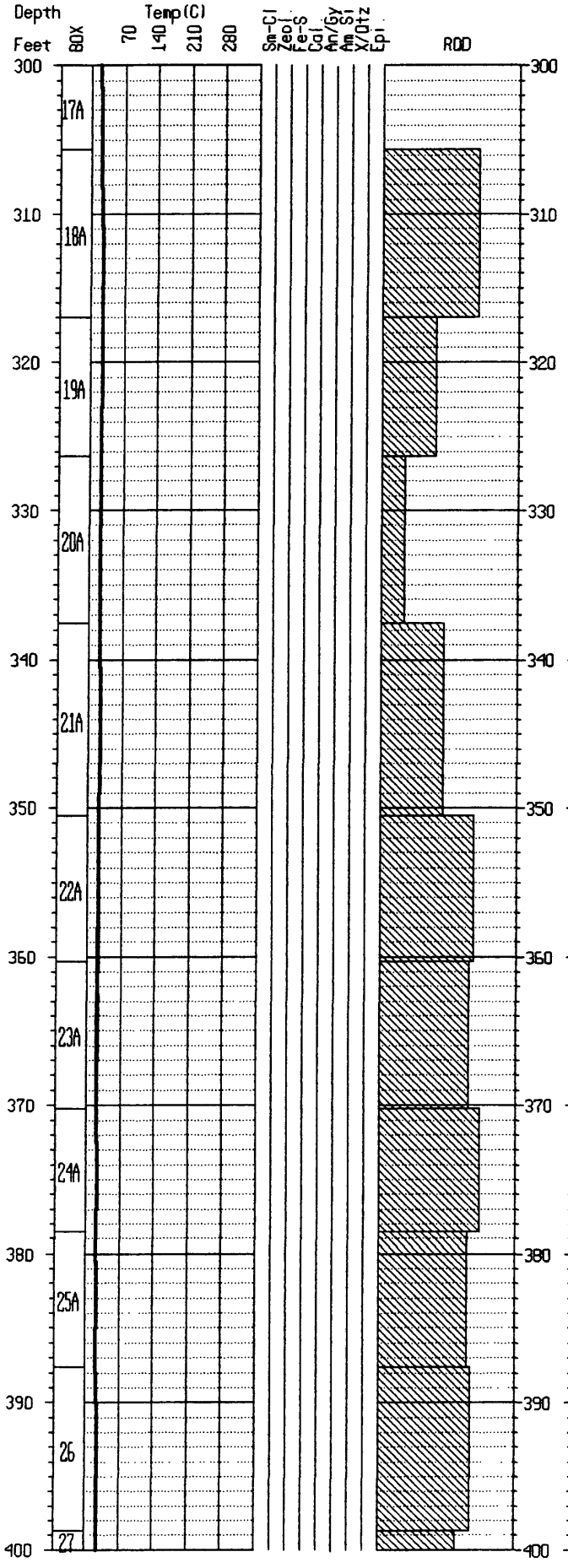
Lithology	Descriptions
	AA, here may just be clinker blocks. 2) A'a with 5% plagioclase phenocrysts, laths, blades and microphenocrysts, 5% olivine phenocrysts and rare olivine-plagioclase intergrowths. groundmass is dark gray.
	AA, flow with 5% plagioclase as phenocrysts, bladed, rhombs and microphenocrysts; <<1% olivine phenocrysts and olivine-plagioclase intergrowths. groundmass is feldspathic and light gray in color.
	AA with 5% plagioclase phenocrysts, blades, microphenocrysts, <<1% olivine and olivine-plagioclase intergrowths in a feldspathic matrix. 2) Pahoehoe with 3% plagioclase lath and microphenocrysts in a dark gray matrix.
	LOST CORE WHEN CHANGING DRILL SIZE.
	AA, <1% plagioclase and olivine phenocrysts in a feldspathic light gray matrix. 2) A'a thin bedded unit with 2-3% plagioclase phenocrysts and laths. Unit 2 is thermally oxidized, the groundmass is a dark bluish gray color.
	AA, 2-3% plagioclase as rhombs, blades, laths, microphenocrysts in a dark blue groundmass; rare gabbro; 2 AND 3) A'a, 2-3% plagioclase, rhombs, laths in a dark gray matrix. Rare olivine and/or olivine-pyroxene grains seen. 4) A'a, 2-3% plagioclase as fibrous clots, laths, microlaths in a dark blue feldspathic matrix.
	AA, 2-3% plagioclase in a dark gray feldspathic matrix. 2) Clinker, has greater abundance of plagioclase phenocrysts, microphenocrysts as fibrous intergrowths, microlaths, groundmass: dark bluish gray.
	AA core, dense with 7% plagioclase as phenocrysts, microphenocrysts and laths, olivine and olivine-plagioclase intergrowths at <<1% in a feldspathic matrix. 2) Pahoehoe with 3% plagioclase as phenocrysts, microphenocrysts in a dark gray matrix.
	AA, 2-3% plagioclase as clots, microphenocrysts and <<1% olivine-plagioclase intergrowths. groundmass is feldspathic and light gray in color. 2) Transitional, 3-5% plagioclase as clots, mostly as microphenocrysts <1mm, groundmass is feldspathic bluish gray in color. 3) Pahoehoe, 3-5% plagioclase clots, mostly microphenocrysts, groundmass bluish gray color rare olivine phenocrysts found.
	PAHOEHOE units with 3-5% plagioclase phenocrysts, as intergrowths, blades and mphs. The groundmass is feldspathic and light gray.
	PAHOEHOE units (5) with 1-3% plagioclase as phenocrysts, microphenocrysts in a gray to light gray feldspathic matrix
	PAHOEHOE; see next page for description.

CATALOG OF SOH 4 CORE



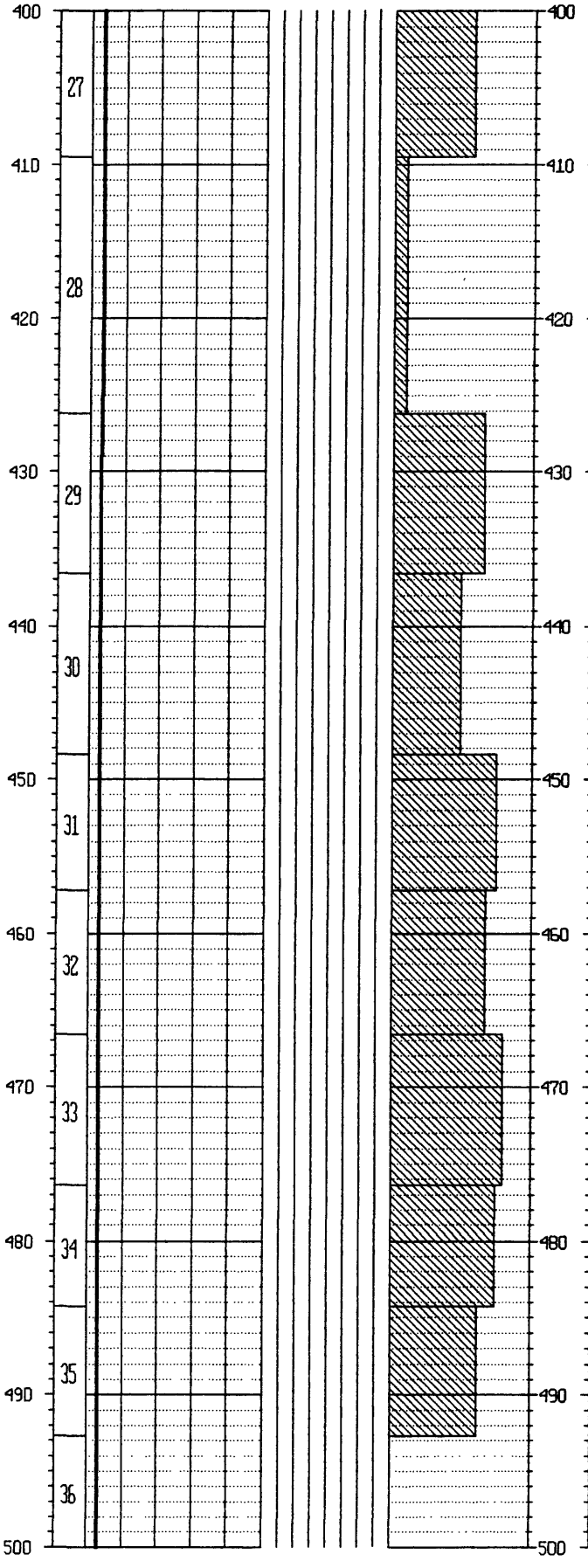
Lithology	Descriptions
	PAHOEHOE, 2) thin unit, oxidized with 3% plagioclase and olivine-plagioclase intergrowths (common) in a dark gray groundmass.
	PAHOEHOE with dense core, thermally oxidized with 3% plagioclase and olivine-plagioclase intergrowths in a feldspathic groundmass. 2) Pahoehoe with 7-10% olivine phenocrysts and 3% plagioclase phenocrysts, laths in a feldspathic graundmass, light gray in color.
	AA, dense with 3-4% plagioclase blades, rhombs and microphenocrysts, olivine phenocrysts rare and olivine-plagioclase intergrowths more common(<1%). The groundmass is feldspathic and light gray in color. 2) Pahoehoe dense, with 2-3% plagioclase as microphenocrysts and laths, <<1% rare olivine-plagioclase intergrowths. The groundmass is light gray and feldspathic .
	PAHOEHOE, with 2% plagioclase laths and microphenocrysts in a feldspathic light gray groundmass; olivine-plagioclase intergrowths are rare. 2) Pahoehoe thin with 3% plagioclase as phenocrysts, blades, microphenocrysts; olivine-plagioclase intergrowths common (1%) all in a light gray feldspathic groundmass. 3) Pahoehoe 3% plagioclase as phenocrysts, blades, microphenacrysts with olivine-plagioclase intergrowths all in a feldspathic, fine grained light gray groundmass.
	PAHOEHOE with 1% plagioclase phenocrysts and microphenocrysts in a light gray feldspathic groundmass. 2) Pahoehoe with 3% plagioclase as phenocrysts, and microphenocrysts in a light gray feldspathic, groundmass; 3) Pahoehoe thermally oxidized unit, with 3% plagioclase phenocrysts and microphenocrysts, blades in a diktytaxitic groundmass; 4) Pahoehoe multiple small units with glassy rinds of similar lithology 5% plagioclase as microphenocrysts in a bluish gray groundmass.
	PAHOEHOE with 3% plagioclase as microphenocrysts in a light gray almost diktytaxitic groundmass. 2) Pahoehoe with 2-3% plagioclase as microphenocrysts in a dark gray groundmass.
	PAHOEHOE with 1% plagioclase as rhombs, laths rare olivine phenocrysts in a diktytaxitic groundmass. 2) Pahoehoe with 1% plagioclase lath, microphenocrysts in a bluish gray groundmass. 4) Pahoehoe with 3-5% plagioclase as microphenocrysts in a bluish gray groundmass. 5) A'a with 5% plagioclase as rhombs, blades, clots in a bluish gray groundmass, portion of the flow thermally oxidized, rare olivine-plagioclase intergrowths.
	AA, 3-4% plagioclase as phenocrysts, blades and microphenocrysts with rare olivine-plagioclase intergrowths in a feldspathic groundmass; 2) A'a, with 5% plagioclase and phenocrysts, blades, rhombs, and microphenocrysts, olivine-plagioclase intergrowths 3% all in a feldspathic gray groundmass; microgabbroic clots at <<1%.
	AA, 5% plagioclase as phenocrysts rhombs and laths, microphenocrysts laths, also rare olivine-phenocrysts in a light gray feldspathic (sugary) graundmass. 2) A'a, plagioclase found at 3% as rhombs, blades and as microlaths. groundmass is sugary and bluish gray in color.
	AA, 5% plagioclase as microphenocrysts, phenocrysts, olivine rare, in a bluish gray sugary groundmass. 2) A'a, 3% plagioclase as blades, microlaths in a bluish gray groundmass; rare olivine phenocrysts.

CATALOG OF SOH 4 CORE



Lithology	Descriptions
	AA, 3) A'a, 3% plagioclase as rhombs, blades and microphenocrysts with 1% olivine as phenocrysts in a bluish gray groundmass. 4) A'a with 1-2% plagioclase phenocrysts, microlaths in a bluish gray groundmass, olivine rare.
	AA, core with <1% plagioclase as bladed phenocrysts in a light gray feldspathic groundmass. 2) A'a with 1% plagioclase phenocrysts in a bluish gray groundmass. 3) Proximal A'a with 5% olivine-plagioclase intergrowths, 3% olivine phenocrysts and 3% plagioclase phenocrysts and laths all in a gray feldspathic groundmass.
	AA, <1% plagioclase blebs and laths in a light gray feldspathic groundmass. 2) Aa, 3% olivine and plagioclase as rhombs, olivine-plagioclase intergrowths in a light gray feldspathic groundmass. 3) Aa, <1% plagioclase laths and olivine in a light gray feldspathic groundmass.
	PAHOEHOE, rubble, <1% plagioclase as laths in a dark bluish gray groundmass. Units 2 to 6) Same lithology as Unit 1.
	AA, micro plagioclase-olivine intergrowths, microlites of plagioclase in a light gray feldspathic groundmass. 2) A'a, plagioclase blades, laths and rhombs in a gray feldspathic groundmass.
	AA, with 3-4% plagioclase as laths and microphenocrysts in a light gray feldspathic groundmass. 2) Transitional flow vesicular top with dense core contains 1% plagioclase as laths, microphenocrysts in a bluish gray groundmass.
	AA to Transitional flow with 1% plagioclase as laths within a light gray feldspathic groundmass. 2) Pahoehoe, jumbled lobes/rubble with <<1% plagioclase as laths in a dark gray groundmass. 3) Pahoehoe with 1% plagioclase within a feldspathic groundmass bluish gray in color
	PAHOEHOE, with 1% plagioclase as laths in a bluish gray sugary groundmass. 2) Transitional flow with 1% plagioclase as rhombs and blades in a feldspathic groundmass.
	AA, <<1% plagioclase in a light gray feldspathic groundmass. 2) Pahoehoe, top 120 cm light pinkish gray grades to light gray feldspathic groundmass for rest of box, <<1% plagioclase found.
	PAHOEHOE, with 3% olivine phenocrysts light green in color with 4% plagioclase as laths, microlaths in a sugary bluish gray groundmass; Unit 1 has an internal contact 2)Transitional, 1% plagioclase as rhombs, blades, and microlaths in a feldspathic light gray groundmass.
	TRANSITIONAL, see next page for description.

CATALOG OF SOH 4 CORE



Lithology

Descriptions

Transitional, 1% plagioclase as, rhombs, blades and laths in a feldspathic fine grained groundmass. 2) Transitional, with 3% olivine phenocrysts, 1% olivine-plagioclase intergrowths and 2% plagioclase as equant, blades and microlaths; groundmass is dark bluish gray. PAHOEHOE, 3) Dike-like unit intruded the void space of the Transitional unit. This unit has 3-5% plagioclase as laths and microphenocrysts all in a bluish gray groundmass.

CLINKER, 1st 61 cm of dense clinker with 1% plagioclase as laths in a charcoal gray groundmass. 2) Vesicular clinker 15-20%, with 2-3% plagioclase as equant Rhombs and laths in dark gray groundmass

AA, with 1% olivine phenocrysts and 1% olivine-plagioclase intergrowths; 3-5% plagioclase as laths, and microphenocrysts in a bluish gray groundmass. 2) Transitional, with 1% olivine phenocrysts, olivine-plagioclase intergrowths; 5% plagioclase laths, some microphenocrysts, groundmass is feldspathic and dark gray.

AA with 3-5% plagioclase as laths and occasional rhombs in a feldspathic light gray groundmass. 2) Transitional flow with <1% plagioclase as laths, microphenocrysts in a light gray feldspathic groundmass.

AA with 1% plagioclase as equant phenocrysts, microphenocrysts and laths in a light gray feldspathic groundmass. 2) A'a, 1% plagioclase as lath and microphenocrysts an occasional larger phenocrysts seen. The groundmass is gray.

AA with 1-3% plagioclase rhombs and laths in a light gray feldspathic groundmass, bottom 39 cm thermally oxidized to dark reddish gray. 2) A'a, aphyric, top 23 cm thermally oxidized to dark reddish gray, remainder of unit light gray feldspathic groundmass.

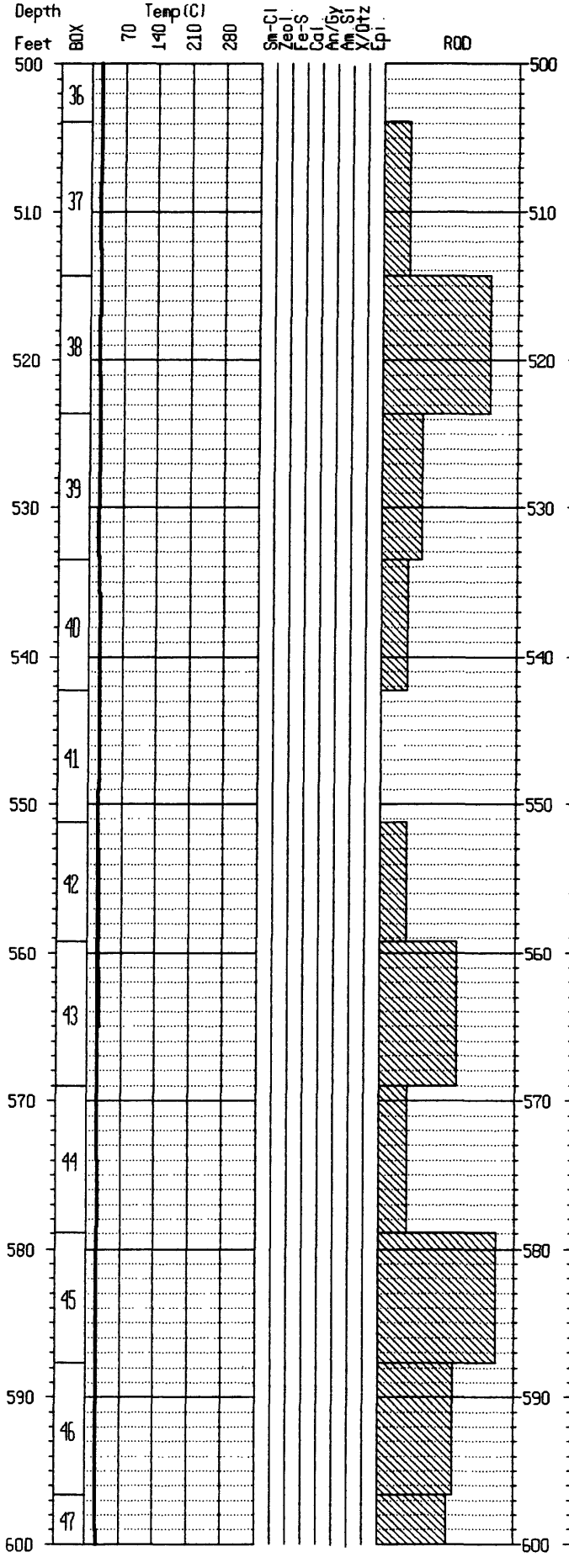
AA, aphyric, light gray feldspathic groundmass; bottom 28 cm thermally altered to dark gray. 2) Pahoehoe, 1% plagioclase as laths in a light gray feldspathic groundmass, top 30 cm thermally oxidized to dark gray, <1% small olivine.

PAHOEHOE, with 1% olivine phenocrysts and 1% olivine-plagioclase intergrowths, 2-3% plagioclase as equant rhombs and mphs. The groundmass is gray and feldspathic. 2) Pahoehoe, with 1% olivine as phenocrysts, microphenocrysts with 1% plagioclase as laths, microphenocrysts in a light gray feldspathic groundmass.

AA, sparsely phyric with plagioclase laths in a light gray feldspathic groundmass.

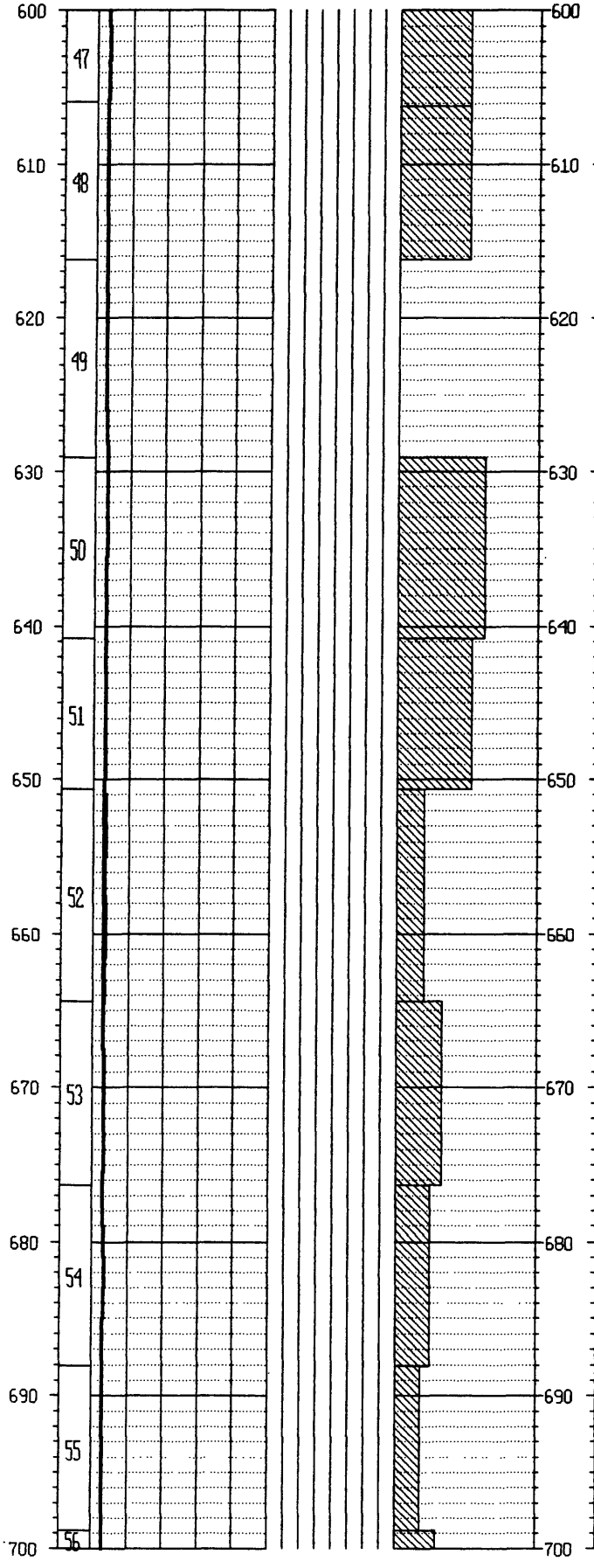
PAHOEHOE, 1% olivine, and <1% plagioclase in a gray groundmass. 2) Pahoehoe, 3% plagioclase laths in an oxidized groundmass. Units 3 & 4) Pahoehoe 10% olivine in an oxidized groundmass 5) Pahoehoe, 5% plagioclase laths in an oxidized groundmass.

CATALOG OF SOH 4 CORE



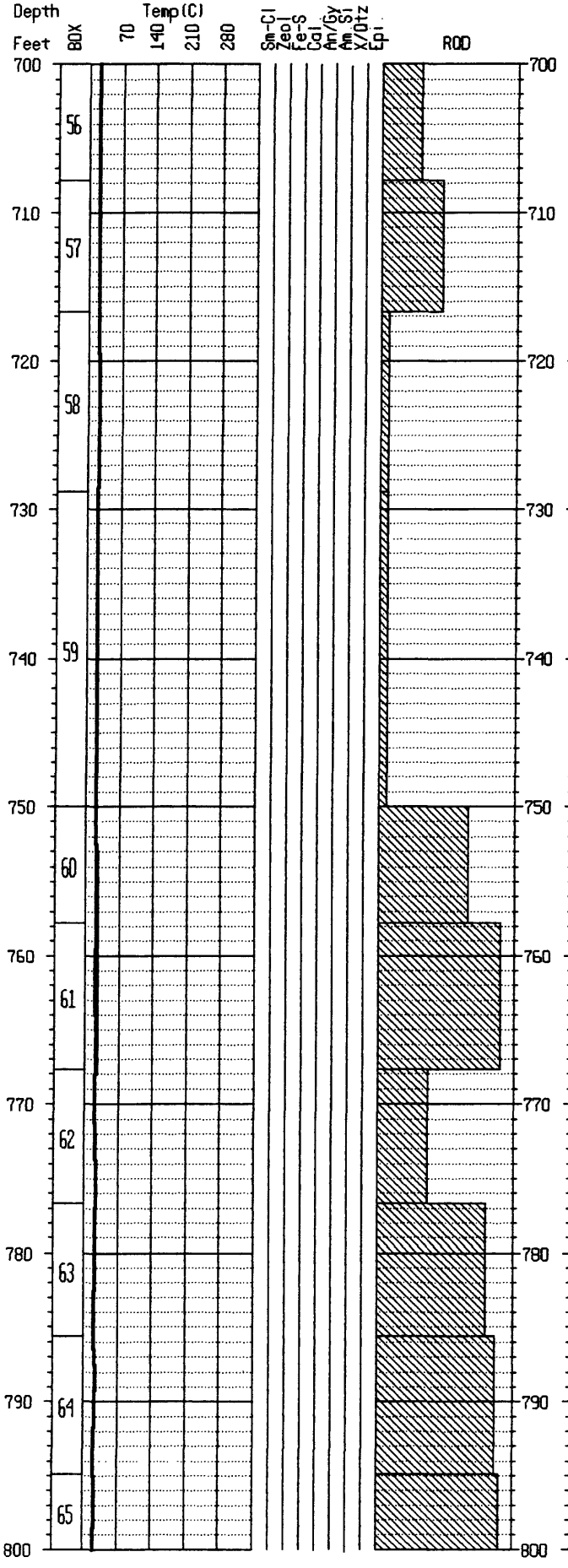
Lithology	Descriptions
	6)Pahoehoe, 3% olivine, 3% plagioclase-olivine phenocrysts, microphenocrysts in a sugary gray groundmass. PAHOEHOE, Units 7 & 8) Pahoehoe 3% plagioclase and phenocrysts, mph, laths in a feldspathic gray groundmass.
	PAHOEHOE, with a medium gray aphyric feldspathic groundmass. 2) Pahoehoe, 1% plagioclase blades, laths and rhombs in a light gray feldspathic groundmass. 3) Pahoehoe, 1% plagioclase blades and laths, <<1% olivine in a thermally oxidized dark reddish gray feldspathic groundmass.
	PAHOEHOE, <1% plagioclase blades and laths in dark reddish gray thermally altered groundmass. 2) Transitional, <1% plagioclase blades and laths in light gray feldspathic groundmass; top 30 cm thermally oxidized to dark reddish gray.
	TRANSITIONAL, <1% plagioclase blades and laths in light gray feldspathic groundmass. 2) Pahoehoe, 1-3% plagioclase blebs and olivine in a gray feldspathic groundmass.
	PAHOEHOE, <1% plagioclase blebs and <1% olivine in a gray feldspathic groundmass. 2) A.a, plagioclase blebs, laths, blades in a light gray feldspathic groundmass.
	AA, <1% plagioclase blebs, laths and blades in light gray feldspathic groundmass. 2) Ash, orange colored, weathered. 3) Pahoehoe, 1-5% olivine, <1% plagioclase laths in a light gray feldspathic groundmass.
	PAHOEHOE, 1-5% olivine, <1% plagioclase laths in a light gray feldspathic groundmass, thermally oxydized.
	PAHOEHOE, with 10% olivine as phenocrysts, microphenocrysts, also rare microgabbros found, in a light bluish gray groundmass. 2) Pahoehoe, picritic, 15-20% olivine as phenocrysts, microphenocrysts in a bluish gray groundmass. 3) Pahoehoe, rubble, picritic basalt; thermally oxidized.
	AA, 1-5% olivine and plagioclase blades, laths and blebs in a pinkish gray feldspathic groundmass.
	AA, 5% olivine phenocrysts and microphenocrysts and 1% plagioclase as equant phenocrysts all in a diktytaxitic feldspathic groundmass.
	PAHOEHOE, 9% olivine phenocrysts (altered), microphenocrysts, plagioclase at 1% as phenocrysts, microphenocrysts in a diktytaxitic, bluish gray groundmass. 2) Pahoehoe, 4% olivine phenocrysts, microphenocrysts in a diktytaxitic thermally oxidized groundmass. Units 3 and 4) Pahoehoe with 6-8% olivine phenocrysts and microphenocrysts in a light gray diktytaxitic groundmass.
	PAHOEHOE, 8% olivine, in a light gray feldspathic GM

CATALOG OF SOH 4 CORE



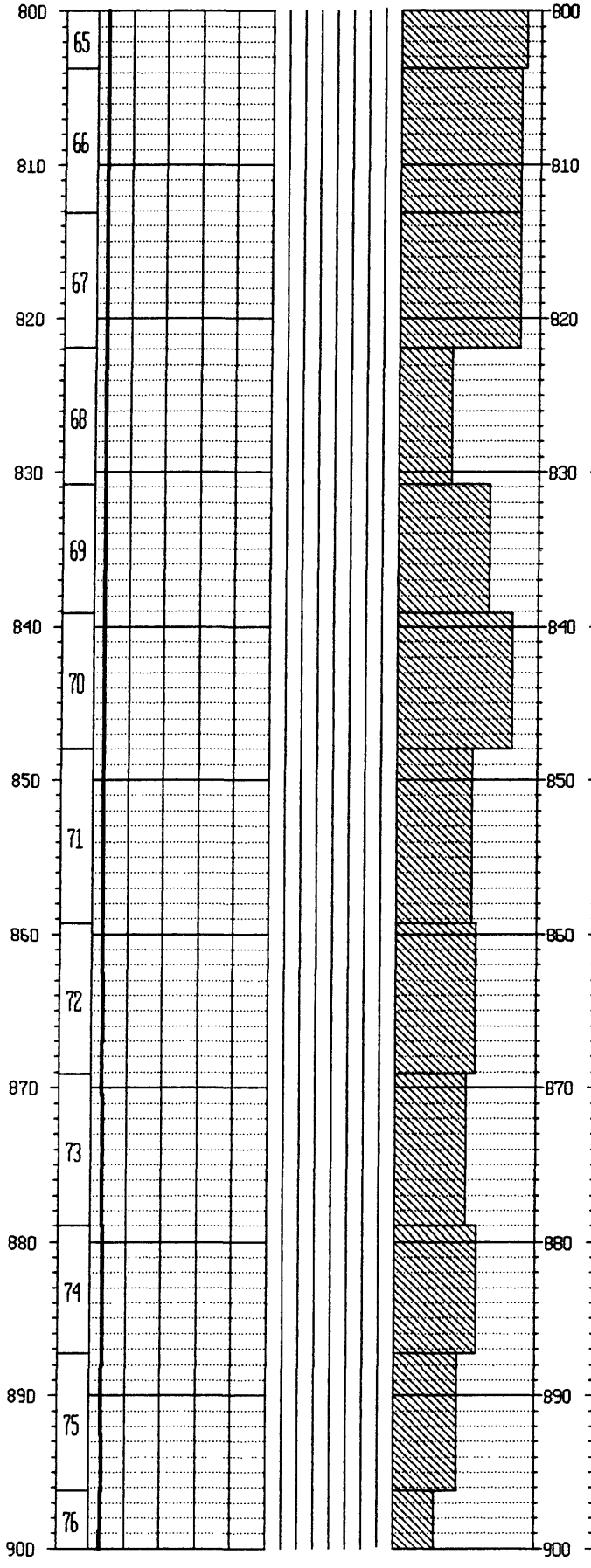
Lithology	Descriptions
	2) Pahoehoe, 3-5% plagioclase blades and laths, and <1% olivine-augite intergrowths in a reddish gray feldspathic groundmass. ASH, Unit 3) weathered, some unaltered glass present, orange in color.
	ASH: weathered, orange in color. 2) Pahoehoe, with 8% olivine-plagioclase intergrowths, 2-4% plagioclase blades and laths in a light gray feldspathic groundmass.
	AA with 5% plagioclase phenocrysts, blades and microphenocrysts, laths, 1% olivine-plagioclase intergrowths all in a gray groundmass. 2) A.a with 5% plagioclase as blades, microphenocrysts, laths in a light gray feldspathic groundmass.
	AA, 5% plagioclase rhombs, blades, and laths in a light gray feldspathic groundmass. 2) Pahoehoe, 5% plagioclase rhombs, blades and laths in a light gray feldspathic groundmass, 1et 75cm thermally altered to light pinkish gray.
	PAHOEHOE, 3% plagioclase as laths, microphenocrysts and <1% olivine-plagioclase intergrowths, all in a light gray feldspathic groundmass. 2) Transitional, 3% plagioclase as phenocrysts, microphenocrysts and 3% olivine-plagioclase intergrowths all in a light gray feldspathic groundmass. 3) Pahoehoe with 1% plagioclase as laths, microphenocrysts all in a gray groundmass. 4) A.a unit with <1% plagioclase as laths, microphenocrysts and <1% olivine-plagioclase intergrowths in a gray groundmass.
	AA, <1% plagioclase blades and laths, <1% olivine, in altered gray feldspathic groundmass. 2) A.a, 2-4% plagioclase blades and laths in a light gray feldspathic groundmass. 3) A.a, <<1% plagioclase blades and laths, <1% olivine (altered) in a light gray feldspathic groundmass.
	AA, 2-4% plagioclase blades and laths in a gray feldspathic groundmass, grades to dark gray at contact. 2) A.a, <<1% plagioclase blades and laths in a gray feldspathic groundmass; light ash coating present between units 1 and 2. 3) Ash, weathered, orange in color, a band of unaltered glass found within ash and branch mold between the contact of units 2 and 3.
	AA, very sparse plagioclase laths and blebs in a gray feldspathic groundmass. 2) A.a, very sparse plagioclase laths and blebs in a light gray feldspathic groundmass, 1 ft core loss between the unit 1-2 contact.
	AA with <1% plagioclase blades and laths in a light gray feldspathic groundmass. 2) orange weathered Ash, some altered glass. 3) A.a, <1% plagioclase blades and laths in a light gray feldspathic groundmass.
	AA, see next page for description

CATALOG OF SOH 4 CORE



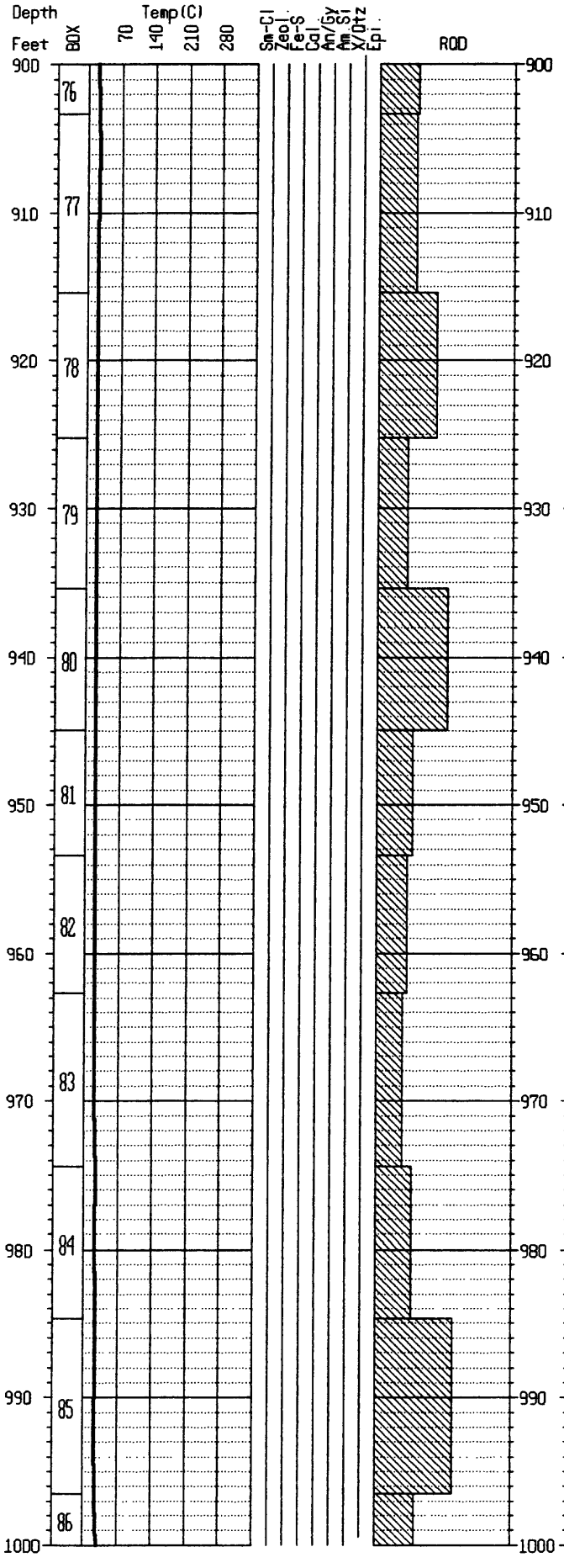
Lithology	Descriptions
	A. a, <1% plagioclase laths and blades in a light gray feldspathic groundmass. AA, Unit 2) plagioclase laths and blades, plagioclase-olivine intergrowths, in a light gray feldspathic groundmass.
	AA, dense core with rare olivine phenocrysts and <1% plagioclase as microphenocrysts all in diktytaxitic light gray groundmass.
	AA, <<1% plagioclase laths and blades in a light gray feldspathic groundmass.
	AA, <1% plagioclase laths and blades in a light gray feldspathic groundmass, with prominent diktytaxitic texture. 2) Sill, plagioclase blebs in a light gray feldspathic groundmass, incorporation of red vesicular clinkers surrounded by chill margin. 3) Pahoehoe, microphyric intergrowths of plagioclase-olivine in a light gray feldspathic groundmass. *******7 feet of core lost here*********.
	PAHOEHOE with <1% olivine as phenocrysts and <1% plagioclase as phenocrysts microphenocrysts all in a bluish gray groundmass. 2) Sill with <1% olivine phenocrysts, microphenocrysts and 1% plagioclase as blades laths, microphenocrysts and plagioclase intergrowths all in a feldspathic groundmass.
	SILL: with <1% olivine, <1% plagioclase as microphenocrysts and rare olivine-plagioclase intergrowths all in a feldspathic light gray groundmass.
	SILL, with <1% olivine phenocrysts, <1% plagioclase microphenocrysts all in a light gray diktytaxitic groundmass. 2) Pahoehoe, 3% plagioclase, as laths, microphenocrysts and intergrowths of olivine-plagioclase. This unit is thermally oxidized red.
	SILL, plagioclase blebs and olivine-plagioclase intergrowths in a light gray feldspathic groundmass.
	SILL, plagioclase blebs and occasional olivine-plagioclase intergrowths in a light gray feldspathic groundmass.
	SILL, with <<1% rare olivine phenocrysts and <1% plagioclase blades and microphenocrysts all in a light gray diktytaxitic groundmass.

CATALOG OF SOH 4 CORE

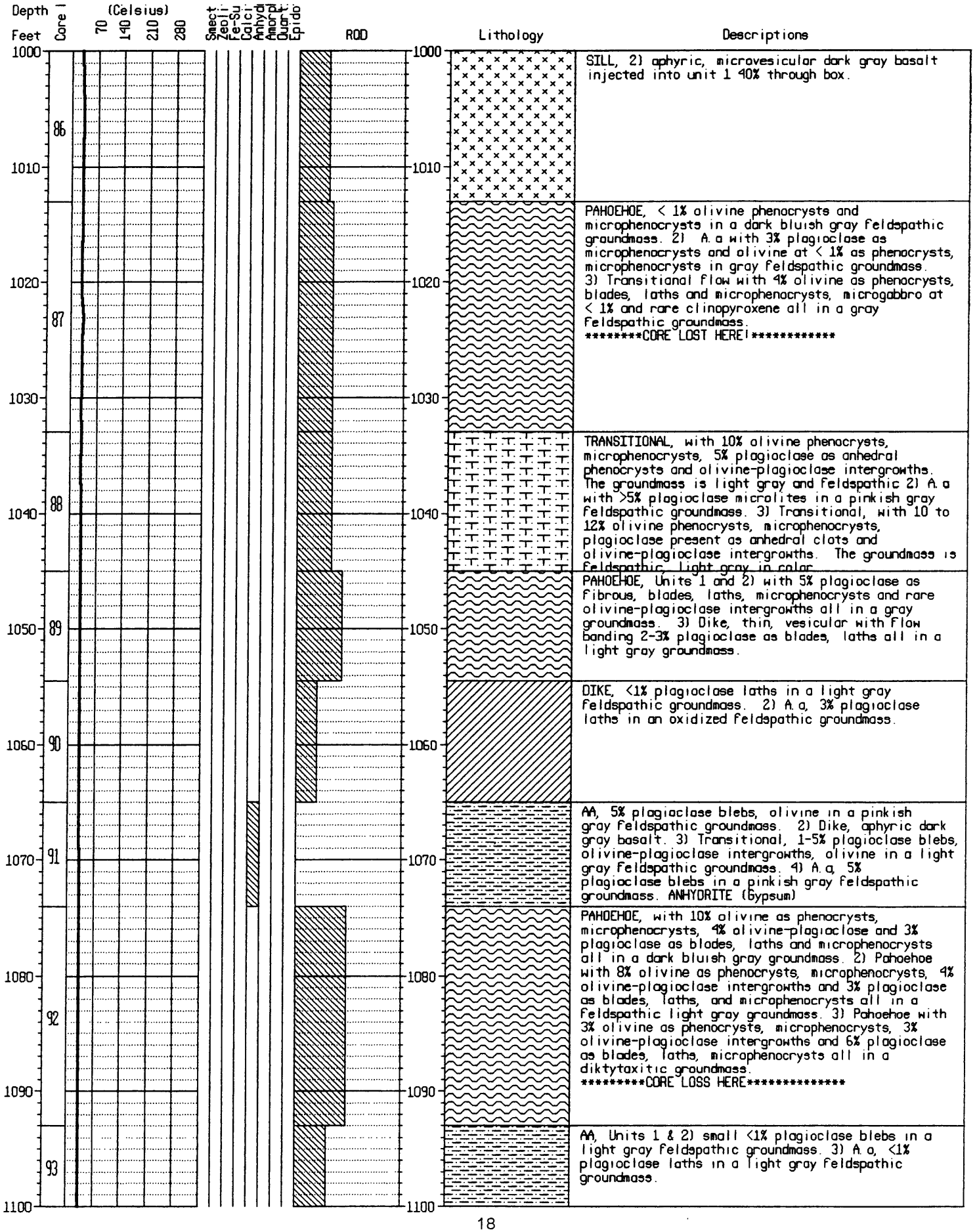


Lithology	Descriptions
	SILL, with <<1% rare olivine phenocrysts and <1% plagioclase blades and microphenocrysts all in a light gray diktytaxitic matrix.
	SILL, with rare olivine phenocrysts and <1% plagioclase as laths and bladed phenocrysts all in a feldspathic light gray matrix.
	SILL, with <1% olivine as microphenocrysts and <1% plagioclase as blades/laths and microphenocrysts all in a light gray diktytaxitic matrix.
	SILL, plagioclase blades and laths, olivine-plagioclase intergrowths in a light gray feldspathic matrix. 2) A'a clinker, highly vesicular, aphyric, red clinker incorporated into unit 1.
	SILL, with <1% rare olivine phenocrysts and <1% plagioclase laths, microphenocrysts in a feldspathic gray matrix.
	SILL, with <1% olivine as phenocrysts, microphenocrysts and <<1% plagioclase as microphenocrysts in a fine gained light gray feldspathic matrix.
	SILL, with <1% olivine as phenocrysts, microphenocrysts and <1% plagioclase as laths and microphenocrysts all in a feldspathic matrix. Units 2 & 4) Pahoehoe unit with 5% plagioclase as rhombs, blades, laths and microphenocrysts. The groundmass when not oxidized is bluish gray. 3) Sill, a tiny intrusion into Unit 2; thickness 20 mm; aphyric and the groundmass is charcoal-black in color.
	PAHOEHOE, 5% plagioclase as phenocrysts, microphenocrysts, laths in a light bluish gray oxidized matrix. 2) Sill, aphyric in a black matrix 3) Pahoehoe with <1% plagioclase as laths in a dark bluish gray matrix.
	PAHOEHOE, with <1% plagioclase as microphenocrysts in a dull gray matrix. 2) Pahoehoe, massive, dense, aphyric, groundmass well-crystallized.
	PAHOEHOE: dense, aphyric, the groundmass is diktytaxitic and light gray. 2) Sill with 3% plagioclase as rhombs, laths, microphenocrysts in a dark bluish gray matrix. 3) Pahoehoe, with 15% olivine phenocrysts and microphenocrysts in a diktytaxitic matrix.
	PAHOEHOE, Units 1 and 2) with 15% olivine as phenocrysts, microphenocrysts in a feldspathic light gray matrix.
	PAHOEHOE, picritic basalt, plagioclase blades, laths and blebs, and olivine-plagioclase intergrowths in a light gray feldspathic groundmass.

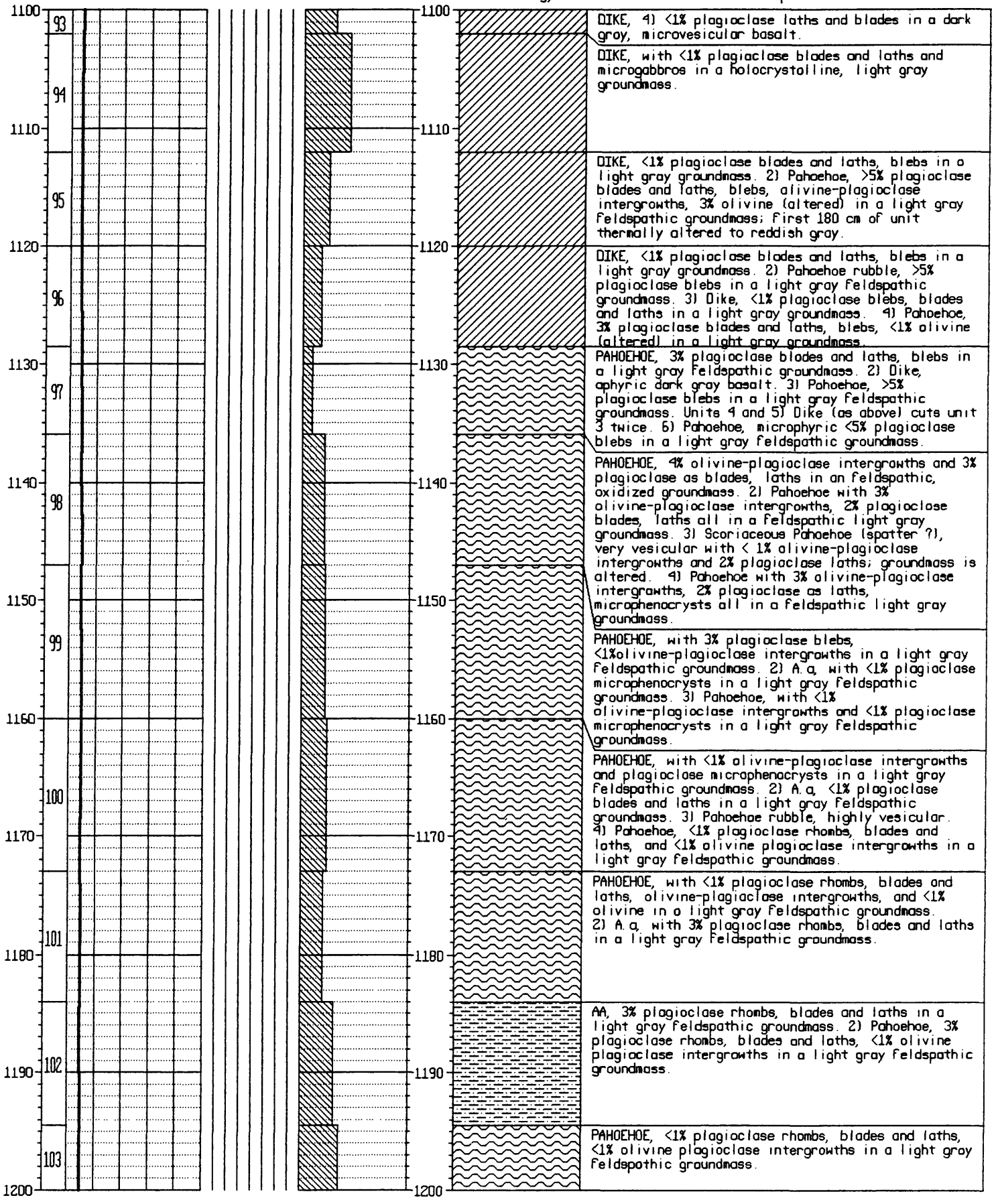
CATALOG OF SOH 4 CORE



Lithology	Descriptions
	2) Ash, altered, orange in color. PAHOEHOE, 3) picritic basalt, plagioclase blades, laths and blebs, olivine, and olivine-plagioclase in a light gray feldspathic groundmass.
	PAHOEHOE, Units 1, 2 and 3) picritic basalt, >5% plagioclase blades, laths, blebs; olivine-plagioclase intergrowths in light gray feldspathic groundmass. 4) A.a, 3% plagioclase blades and laths, <1% olivine in a light gray feldspathic groundmass. 5) Sill, between units 2, 3; 3% plagioclase laths and blades in a dense light gray feldspathic groundmass.
	PAHOEHOE, 1-5% plagioclase blades and laths, olivine-plagioclase intergrowths in a light gray feldspathic groundmass. 2) Sill, 1-5% plagioclase blades and laths in a diktytaxitic light gray groundmass. 3) Pahoehoe, 1-5% plagioclase rhombs, blades, and laths in a light gray feldspathic groundmass.
	PAHOEHOE, 1-5% plagioclase rhombs, blades and laths, olivine-plagioclase intergrowths, olivine in a light gray feldspathic groundmass. Areas of dense vesiculation have been crushed to rubble.
	PAHOEHOE, with 1-5% plagioclase phenocrysts, microphenocrysts and laths. Olivine is present at 1%; all in a light gray diktytaxitic groundmass
	PAHOEHOE, 1-5% plagioclase rhombs, blades and laths, olivine-plagioclase intergrowths, <1% olivine in a diktytaxitic, light gray groundmass. 2) Ash, altered orange in color.
	PAHOEHOE, <1% plagioclase blades and laths, olivine-plagioclase intergrowths in a light gray feldspathic groundmass.
	PAHOEHOE, 1-5% plagioclase blades and laths, olivine-plagioclase intergrowths in a light gray feldspathic groundmass. 2) A.a, 1-5% plagioclase rhombs, olivine-plagioclase intergrowths, and olivine in a light gray feldspathic groundmass.
	AA, <1% rhombs, blades and laths in a light gray feldspathic groundmass
	PAHOEHOE, Units 1, 2) with 1% olivine phenocrysts, microphenocrysts all in a dark bluish gray feldspathic groundmass.
	AA, 1-5% plagioclase microlites, <1% blades and laths, in a light gray feldspathic groundmass.


Depth
Feet
Core
(Celsius)
70
140
210
280
Smect
Zeol
Fe-Su
Calci
Anhyd
Amorp
Quart
Epido
RQD
Lithology
Descriptions
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
1100
86
87
88
89
90
91
92
93
SILL, 2) aphyric, microvesicular dark gray basalt injected into unit 1 40% through box.
PAHOEHOE, < 1% olivine phenocrysts and microphenocrysts in a dark bluish gray feldspathic groundmass. 2) A.a with 3% plagioclase as microphenocrysts and olivine at < 1% as phenocrysts, microphenocrysts in gray feldspathic groundmass. 3) Transitional flow with 4% olivine as phenocrysts, blades, laths and microphenocrysts, microgabbro at < 1% and rare clinopyroxene all in a gray feldspathic groundmass.
********CORE LOST HERE!**********
TRANSITIONAL, with 10% olivine phenocrysts, microphenocrysts, 5% plagioclase as anhedral phenocrysts and olivine-plagioclase intergrowths. The groundmass is light gray and feldspathic 2) A.a with >5% plagioclase microlites in a pinkish gray feldspathic groundmass. 3) Transitional, with 10 to 12% olivine phenocrysts, microphenocrysts, plagioclase present as anhedral clots and olivine-plagioclase intergrowths. The groundmass is feldspathic, light gray in color.
PAHOEHOE, Units 1 and 2) with 5% plagioclase as fibrous, blades, laths, microphenocrysts and rare olivine-plagioclase intergrowths all in a gray groundmass. 3) Dike, thin, vesicular with flow banding 2-3% plagioclase as blades, laths all in a light gray groundmass.
DIKE, <1% plagioclase laths in a light gray feldspathic groundmass. 2) A.a, 3% plagioclase laths in an oxidized feldspathic groundmass.
AA, 5% plagioclase blebs, olivine in a pinkish gray feldspathic groundmass. 2) Dike, aphyric dark gray basalt. 3) Transitional, 1-5% plagioclase blebs, olivine-plagioclase intergrowths, olivine in a light gray feldspathic groundmass. 4) A.a, 5% plagioclase blebs in a pinkish gray feldspathic groundmass. ANHYDRITE (Gypsum)
PAHOEHOE, with 10% olivine as phenocrysts, microphenocrysts, 4% olivine-plagioclase and 3% plagioclase as blades, laths and microphenocrysts all in a dark bluish gray groundmass. 2) Pahoehoe with 8% olivine as phenocrysts, microphenocrysts, 4% olivine-plagioclase intergrowths and 3% plagioclase as blades, laths, and microphenocrysts all in a feldspathic light gray groundmass. 3) Pahoehoe with 3% olivine as phenocrysts, microphenocrysts, 3% olivine-plagioclase intergrowths and 6% plagioclase as blades, laths, microphenocrysts all in a diktytaxitic groundmass.
*********CORE LOSS HERE**********
AA, Units 1 & 2) small <1% plagioclase blebs in a light gray feldspathic groundmass. 3) A.a, <1% plagioclase laths in a light gray feldspathic groundmass.

CATALOG OF SOH 4 CORE



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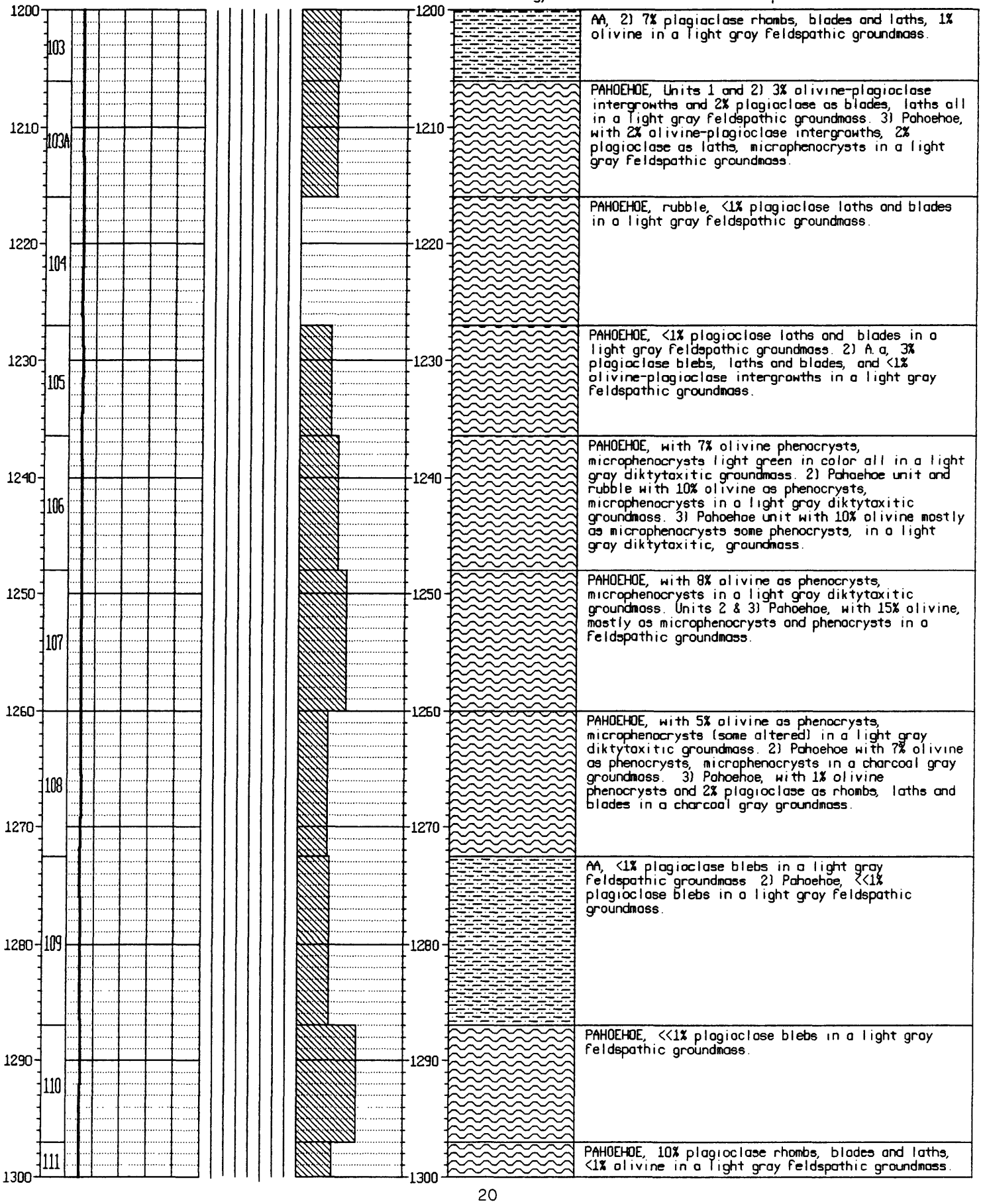

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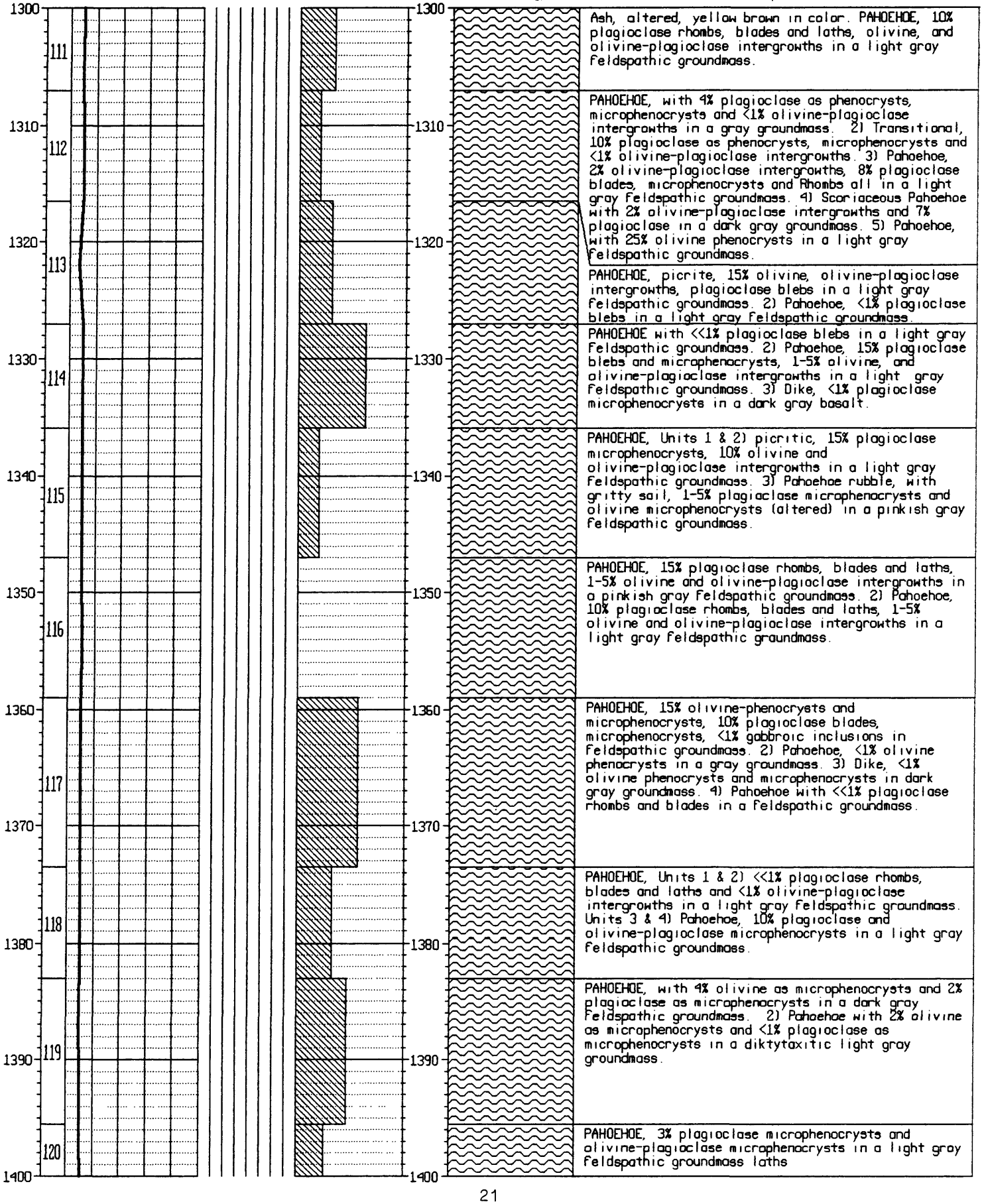

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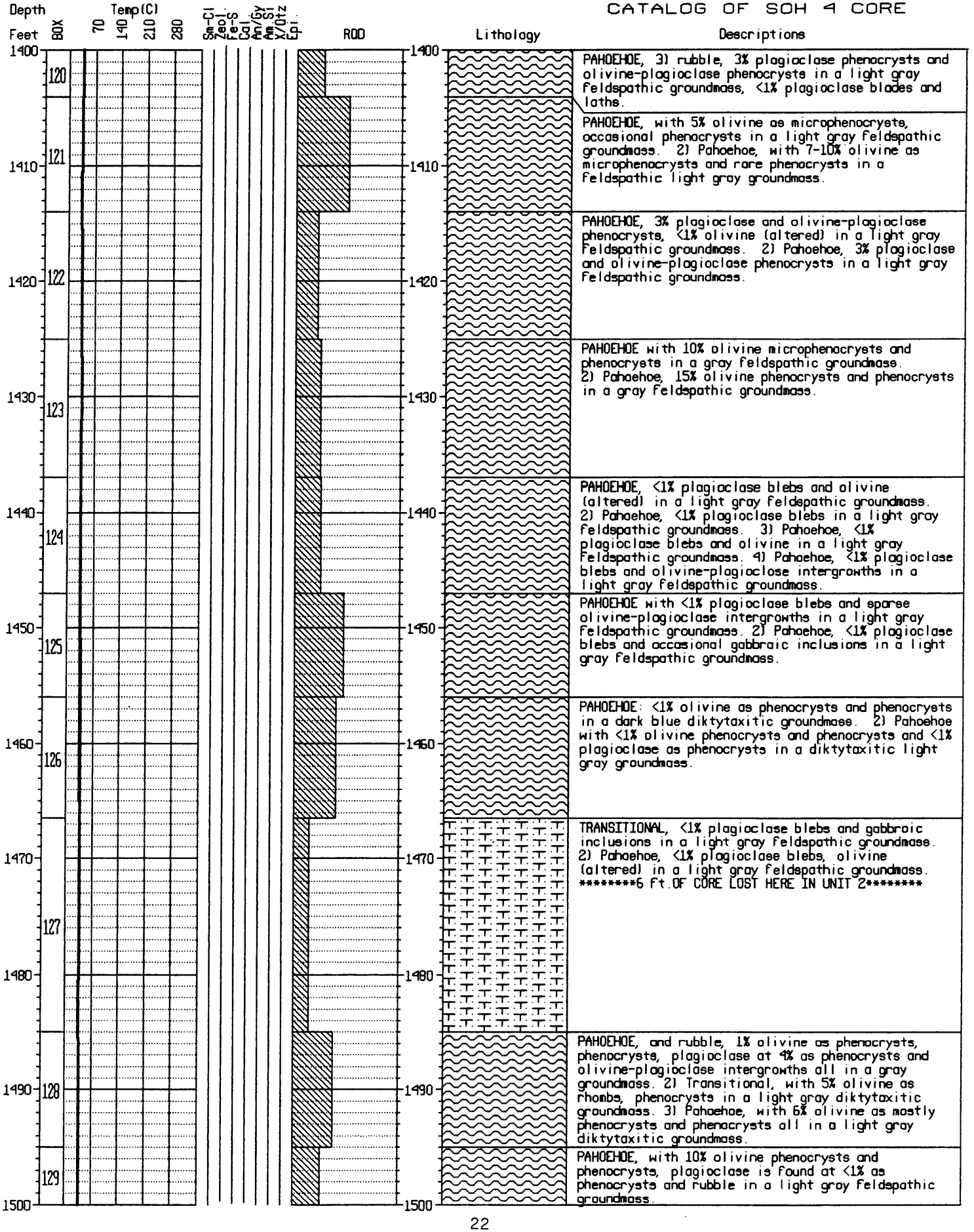

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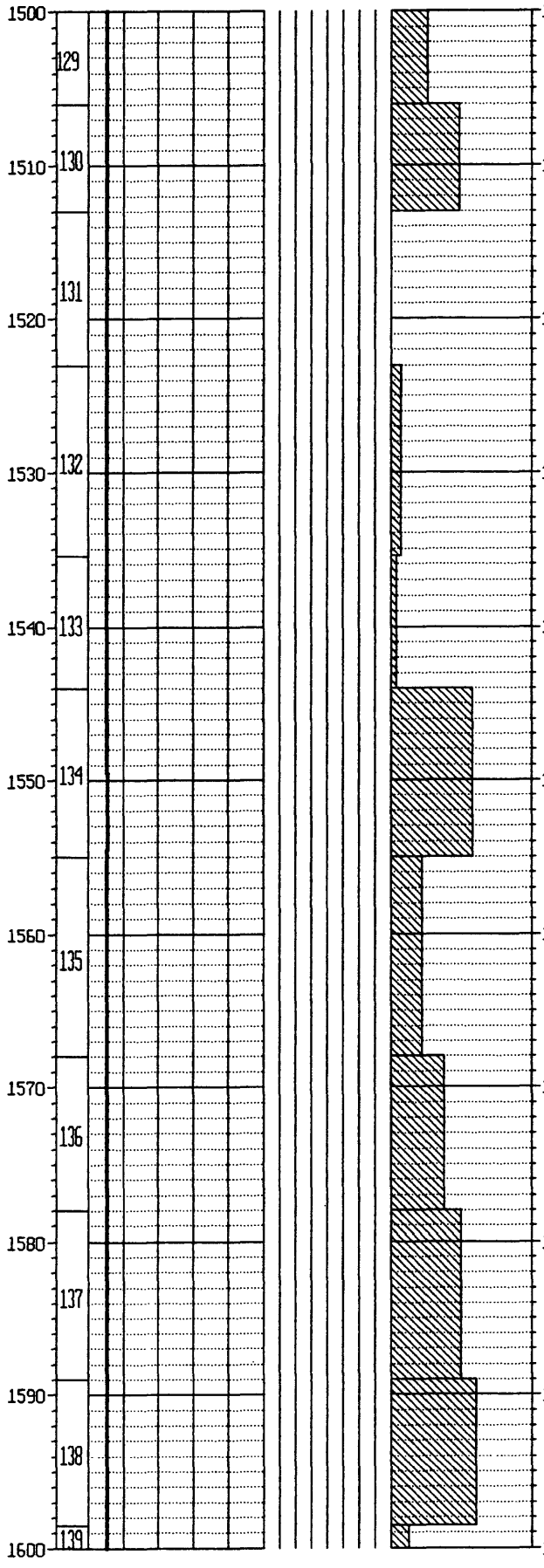


Lithology

Descriptions

PAHOEHOE, and rubble with 7% olivine phenocrysts, microphenocrysts with <1% plagioclase microphenocrysts all in a light gray diktytaxitic groundmass.

PAHOEHOE, Units 1 & 3) with 5% olivine phenocrysts and microphenocrysts in a light gray feldspathic groundmass. 2) Pahoehoe, oxidized, aphanitic, gray-green feldspathic groundmass.

PAHOEHOE, rubble with <1% plagioclase blebs in a light gray feldspathic groundmass. 2) Dike, 3% plagioclase laths, olivine-plagioclase intergrowths, and gabbroic inclusions in a dark gray basalt.

DIKE, with 3% olivine as phenocrysts, microphenocrysts: and plagioclase at 3% as phenocrysts, microphenocrysts and laths in a steel blue groundmass. Gabbros are commonly found. 2) Transitional, with 2% olivine as phenocrysts, microphenocrysts in a gray groundmass. This unit is mostly rubble.

TRANSITIONAL, <1% plagioclase blebs and 2% olivine (altered), olivine-plagioclase in a light gray feldspathic groundmass. 2) Pahoehoe, 1% plagioclase blebs in a light gray feldspathic groundmass.

PAHOEHOE, scoriaceous, 3% olivine phenocrysts, microphenocrysts, olivine-plagioclase intergrowths, plagioclase laths and microphenocrysts and gabbroic inclusions (all totaling <5%), in a feldspathic dark gray groundmass.

PAHOEHOE with 15% plagioclase blebs, olivine-plagioclase intergrowths in a light gray feldspathic groundmass. 2) Breccia, angular, and vesicular clasts 5% plagioclase blebs in a groundmass of red and gray ash. 3) Transitional, 2% plagioclase blebs, blades and laths, and olivine-plagioclase intergrowths in a light gray feldspathic groundmass.

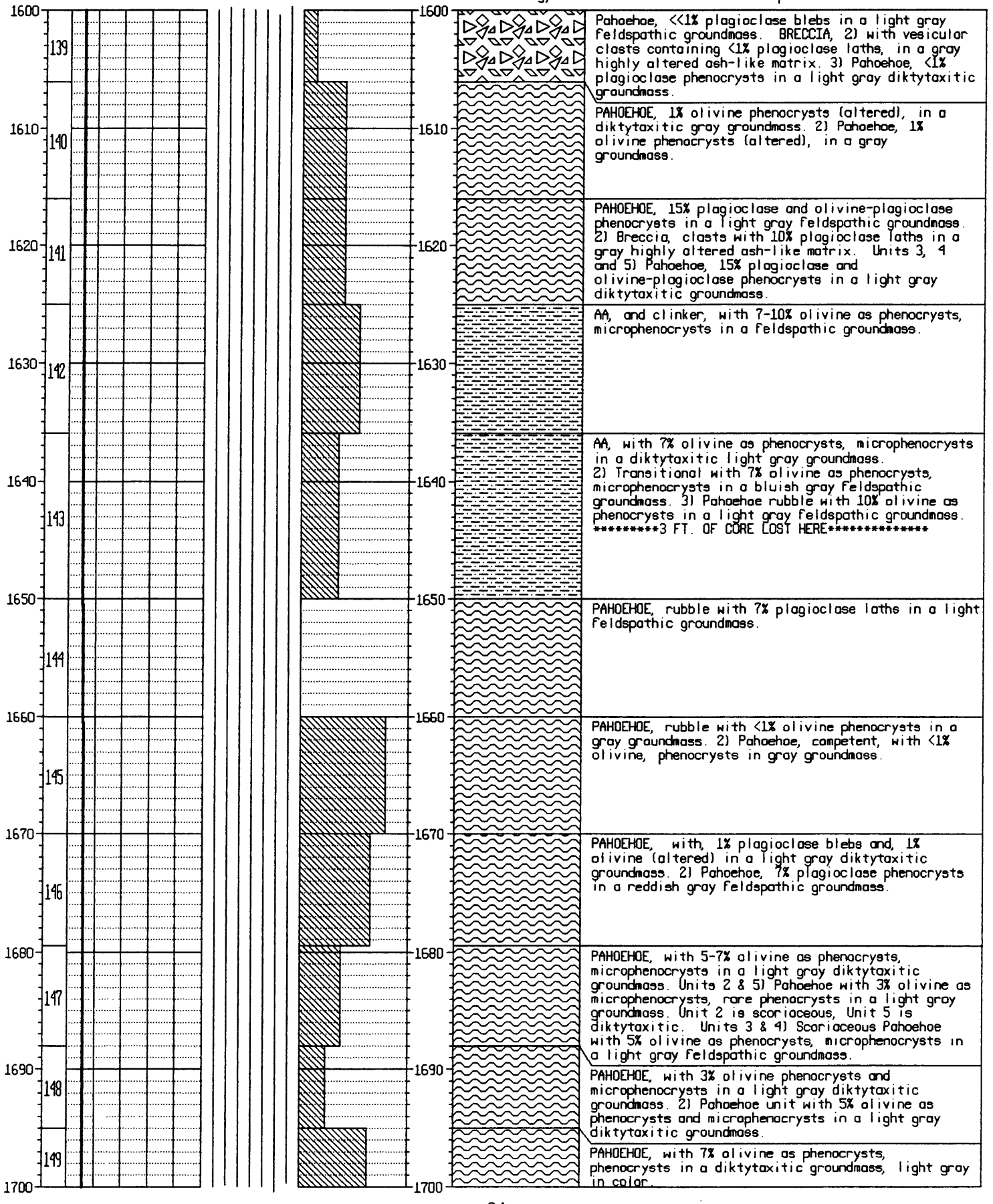
TRANSITIONAL, <1% plagioclase blebs, olivine-plagioclase intergrowths in a light gray feldspathic groundmass. 2) Pahoehoe, 10% plagioclase blebs and olivine-plagioclase intergrowths in a light gray feldspathic groundmass.

PAHOEHOE, 10% plagioclase blades and laths and 5% olivine-plagioclase intergrowths in a light gray feldspathic groundmass. 2) Breccia, angular, vesicular clasts with 10% plagioclase blades, in a red and gray altered Ash-like matrix. 3) Pahoehoe, 5% plagioclase blades, blades and laths in a light gray diktytaxitic groundmass.

AA, 1-5% olivine microphenocrysts, 10% plagioclase laths and microphenocrysts in a diktytaxitic gray groundmass. 2) Pahoehoe, 1% olivine phenocrysts and microphenocrysts in a dark gray feldspathic groundmass. 3) Pahoehoe, fractured with <1% olivine microphenocrysts and <1% plagioclase laths and microphenocrysts in a gray feldspathic groundmass.

PAHOEHOE, see next page for description.

CATALOG OF SOH 4 CORE



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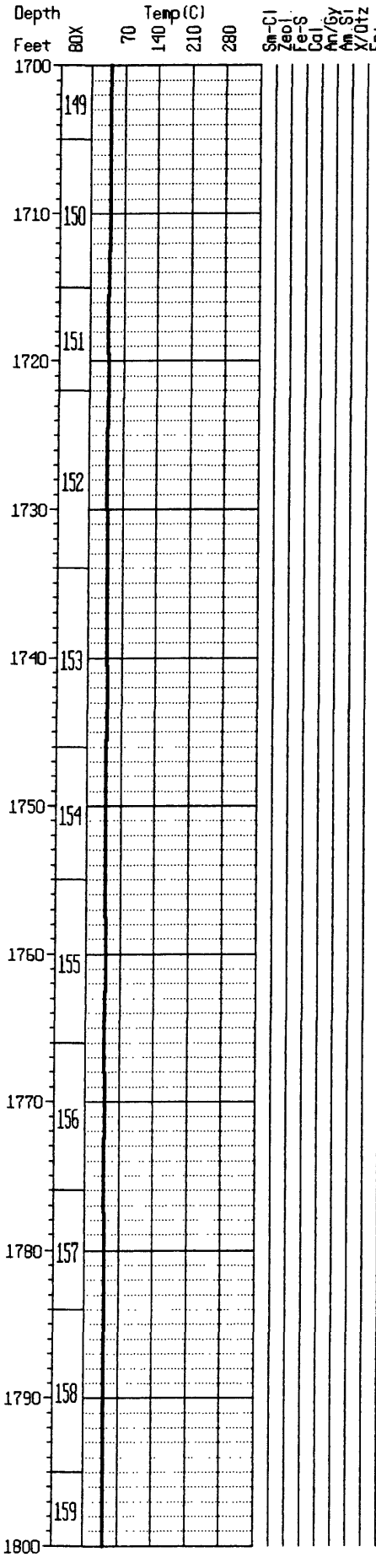
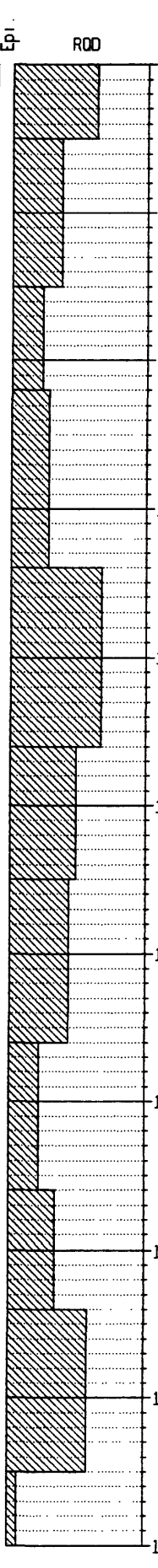
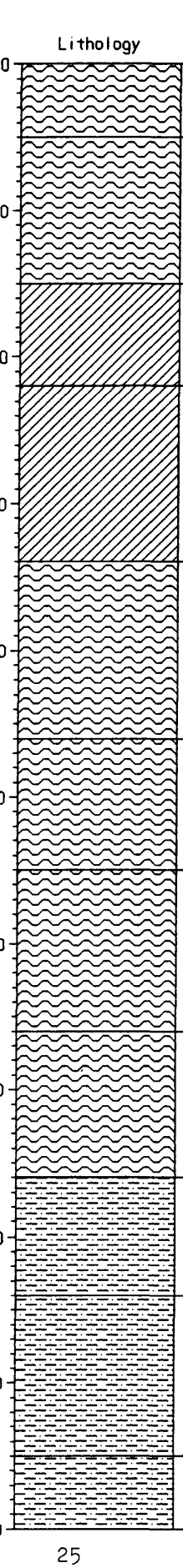
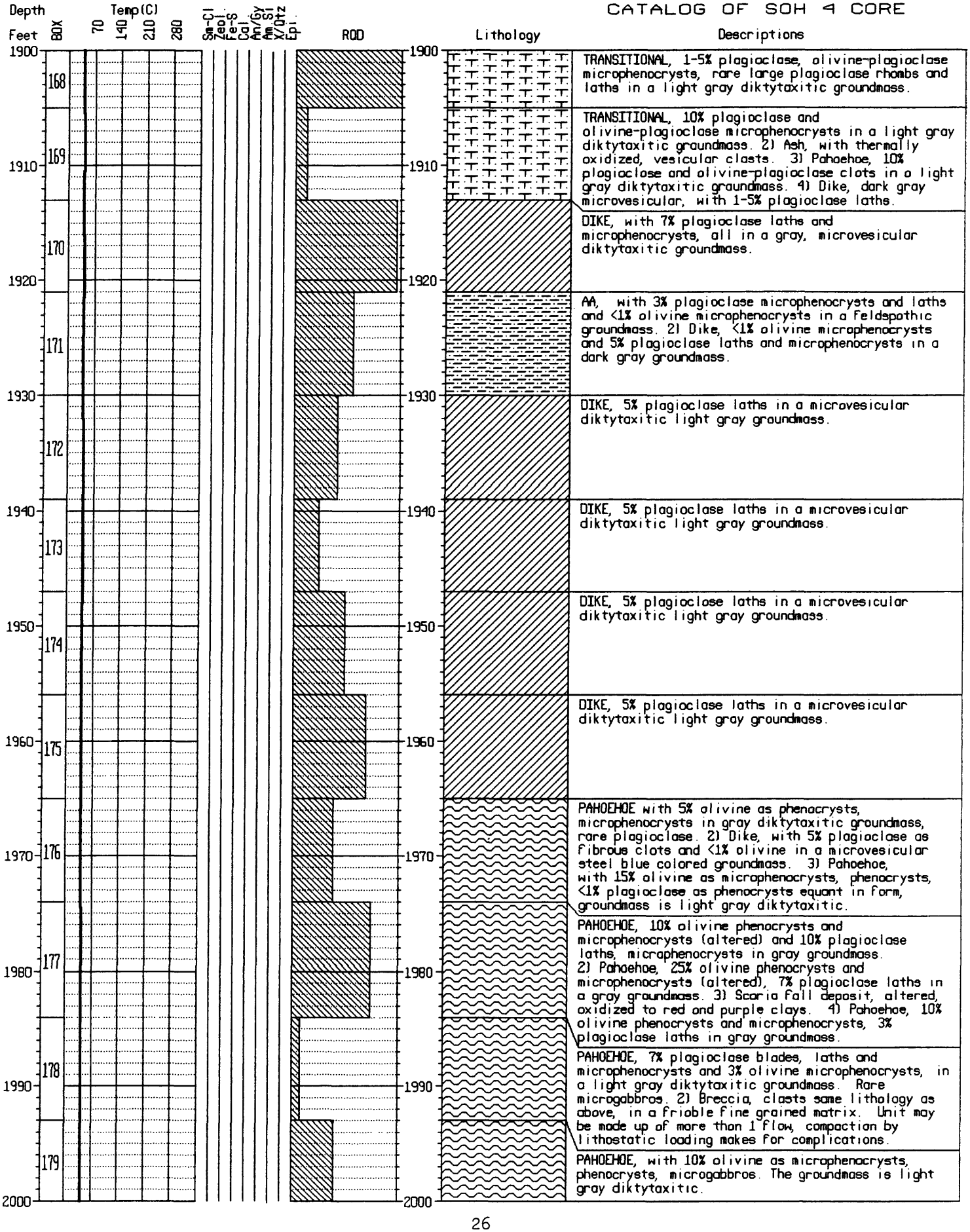






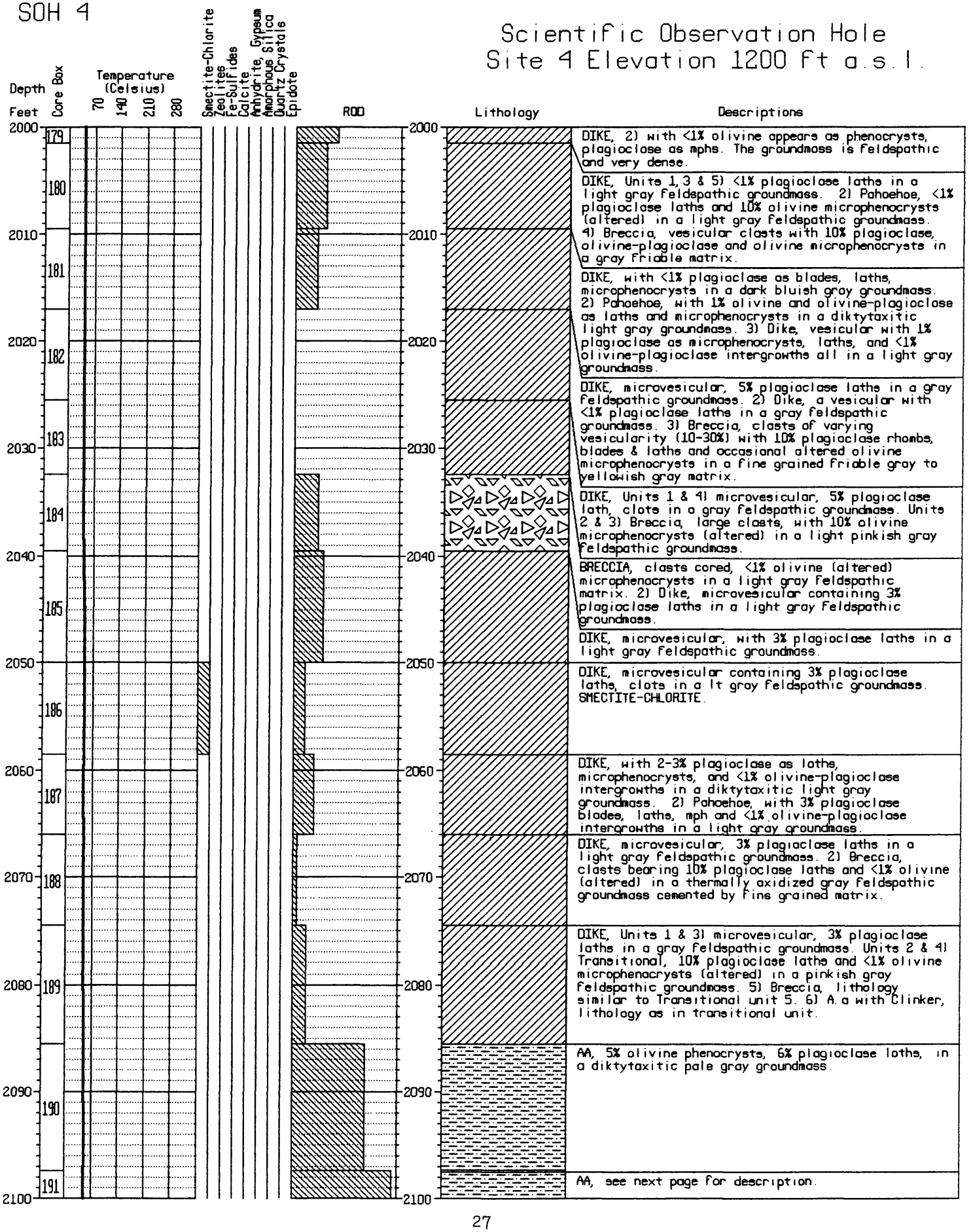
Descriptions
PAHOEHOE, 2) with 5-7% olivine as phenocrysts, microphenocrysts in a light gray diktytaxitic groundmass.
PAHOEHOE with 7% olivine as microphenocrysts in a light bluish gray diktytaxitic groundmass. 2) Dike with 3% plagioclase as blades/laths and microphenocrysts and olivine is present at <1% as phenocrysts in a feldspathic groundmass.
DIKE, with <1% plagioclase lath and blades, rhombs in a microvesicular light gray groundmass.
DIKE, with <1% plagioclase rhombs, laths and blades in a microvesicular light gray groundmass. 2) Pahoehoe, 5% plagioclase rhombs, laths and blades and 5% olivine, and olivine-plagioclase intergrowths in a light gray feldspathic groundmass. **********2 FT OF CORE LOST HERE**********
PAHOEHOE, with 7% olivine as phenocrysts, microphenocrysts and olivine-plagioclase intergrowths, 3% plagioclase as blades, laths and microphenocrysts; the groundmass is diktytaxitic and light gray. 2) Pahoehoe with 10% olivine as phenocrysts, microphenacrysts and plagioclase-olivine intergrowths; 2-3% plagioclase as blades, laths, and microphenocrysts in a feldspathic light gray groundmass.
PAHOEHOE, units 1 & 3) with 5% plagioclase blebs and olivine-plagioclase microphenocrysts in a reddish gray oxidized feldspathic groundmass. 2) Pahoehoe, 5% plagioclase rhombs, blades and laths and 5% olivine-plagioclase intergrowths in a light gray feldspathic groundmass.
PAHOEHOE, rubble with 12% olivine phenocrysts, microphenocrysts in a bluish gray groundmass. 2) Pahoehoe with 7-10% olivine phenocrysts, microphenocrysts in diktytaxitic light gray groundmass; plagioclase is found at 1% in the form of Rhombs and microlaths. 3) Pahoehoe with 10% olivine as microphenocrysts in a dark. Thermally oxidized groundmass.
PAHOEHOE, 1-5% plagioclase rhombs, blades and laths, olivine-plagioclase intergrowths, 3% olivine microphenocrysts in a light gray feldspathic groundmass. 2) Ash, thin unit 5 cm thick, red. 3) Pahoehoe, 1-5% plagioclase rhombs, blades and laths, olivine-plagioclase intergrowths, 3% olivine microphenocrysts in a light gray diktytaxitic groundmass.
AA, and clinker vesicular with 5-7% olivine as microphenocrysts and occasional phenocrysts in a light gray diktytaxitic groundmass.
AA, 3% olivine phenocrysts and microphenocrysts, in a light gray diktytaxitic groundmass.
AA, 1-5% plagioclase laths, olivine and olivine-plagioclase intergrowths in a light gray diktytaxitic groundmass. 2) Ash, containing 20% olivine and olivine-plagioclase clots.

CATALOG OF SOH 4 CORE



SOH 4

Scientific Observation Hole
Site 4 Elevation 1200 ft a.s.l.



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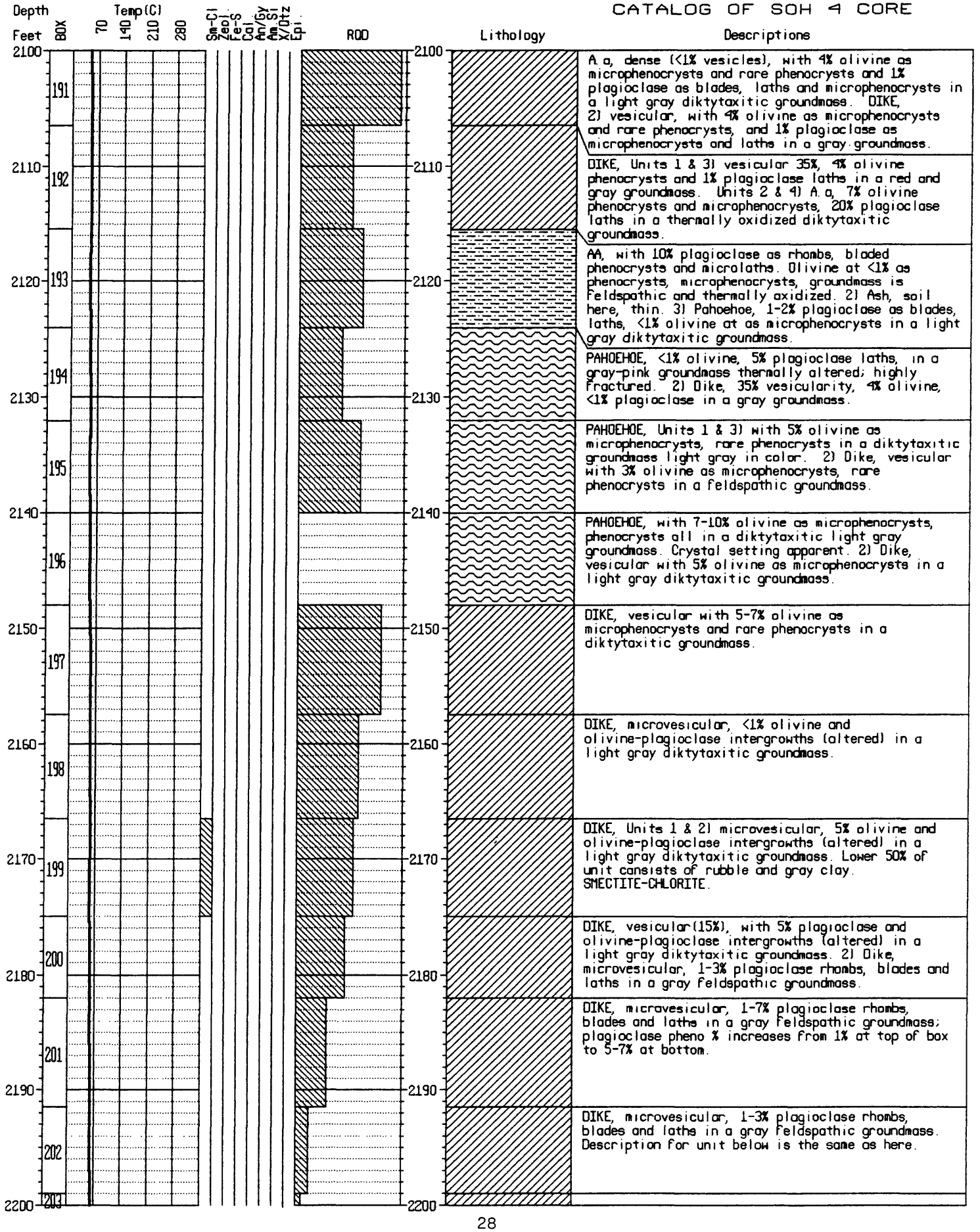

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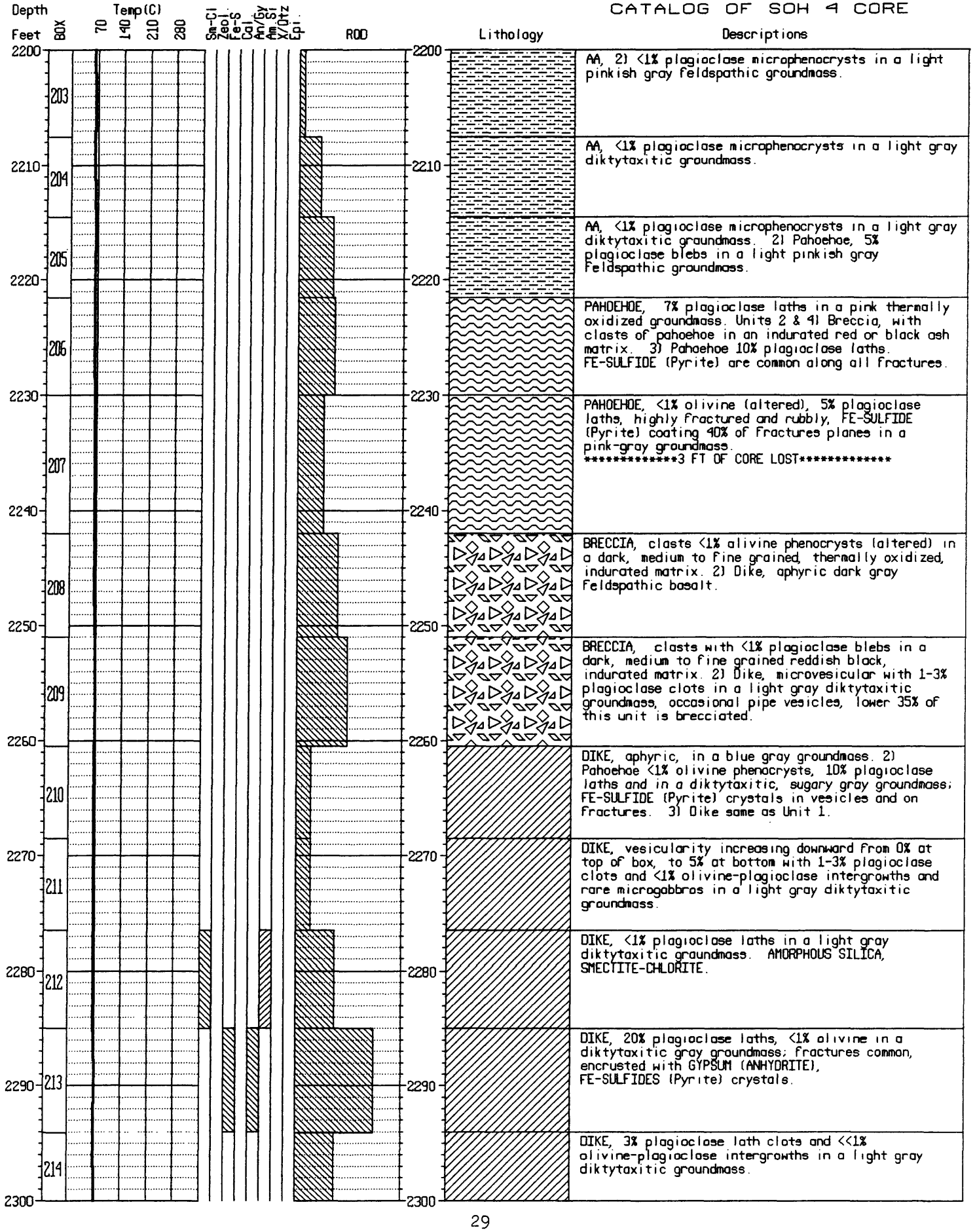

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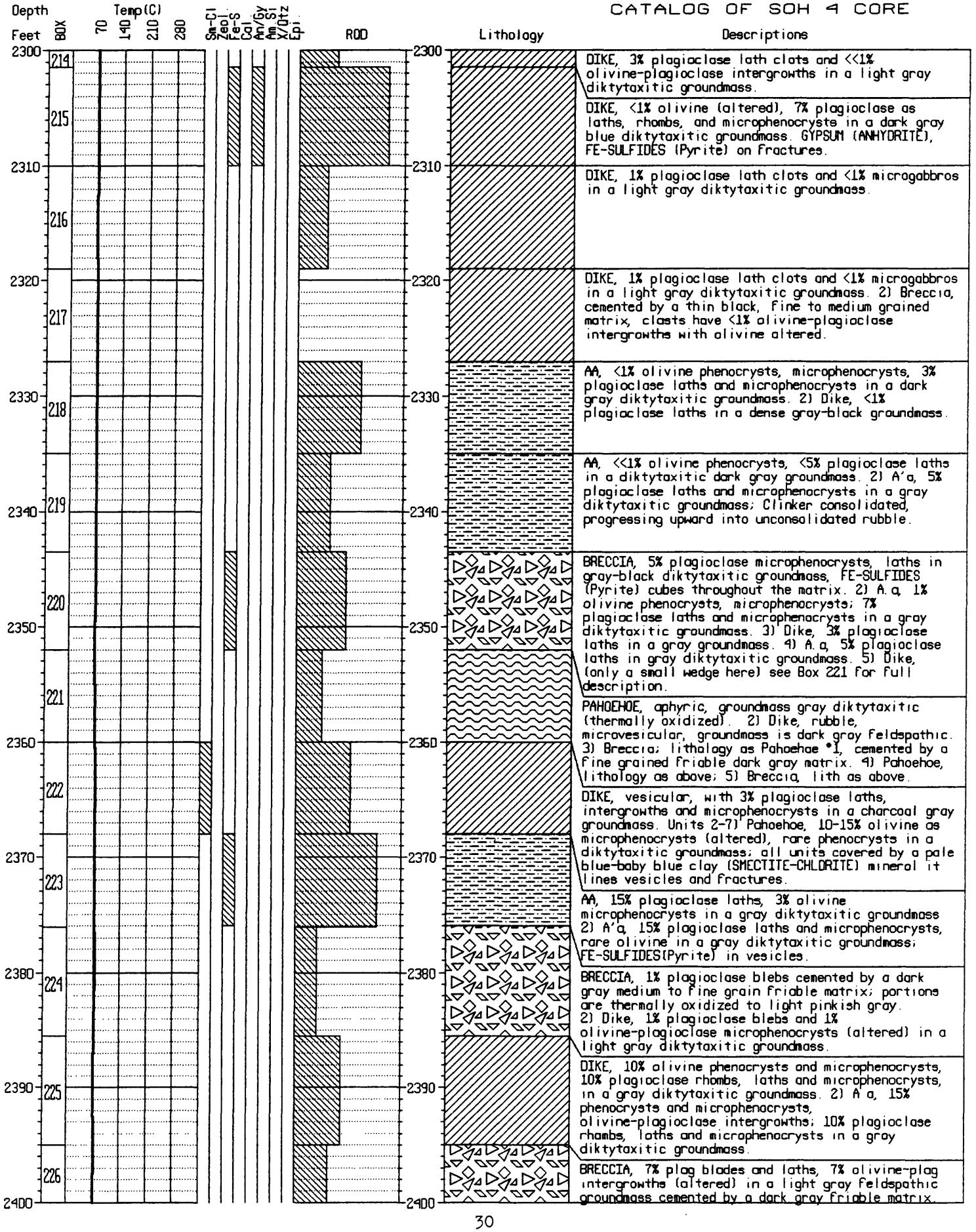

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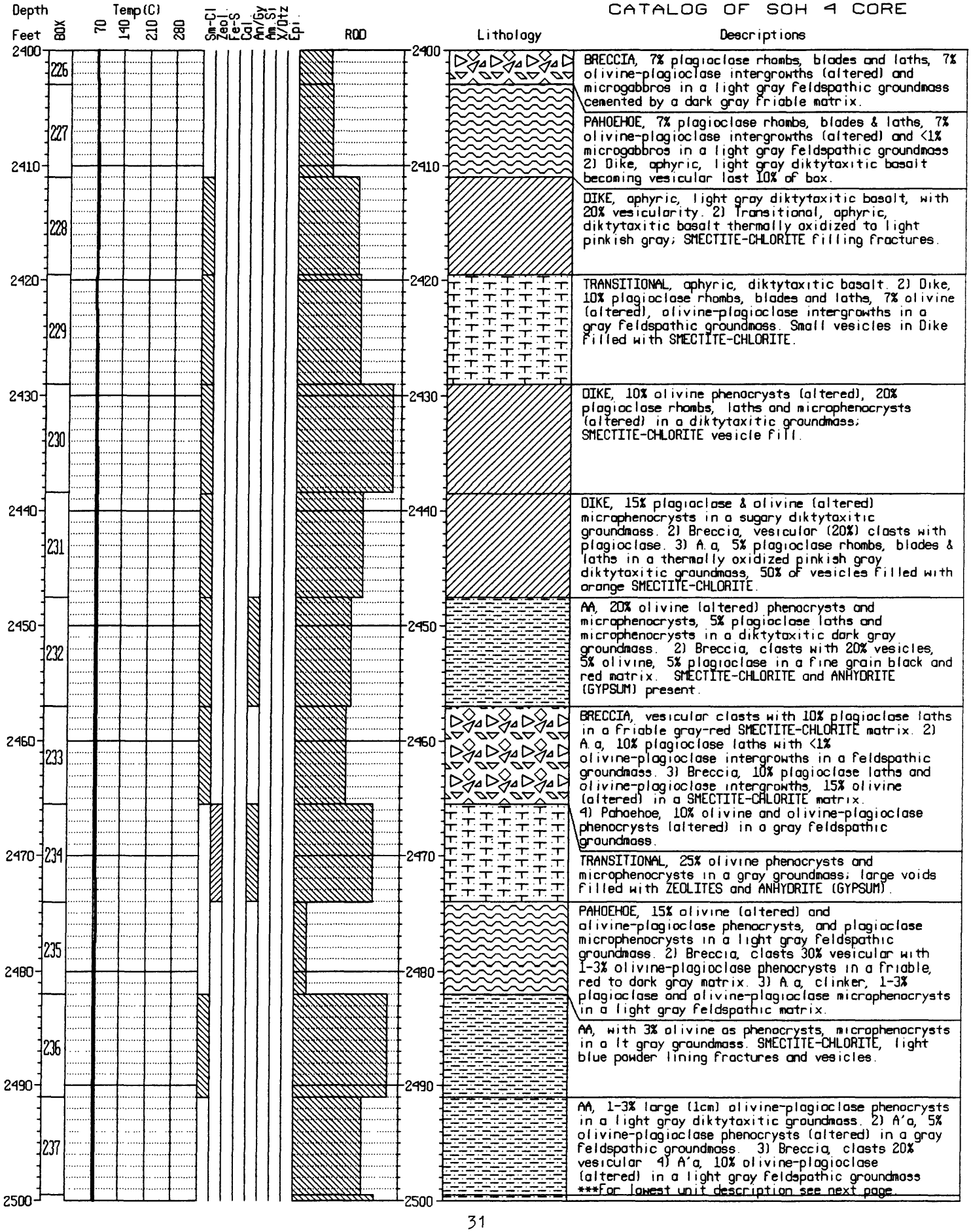

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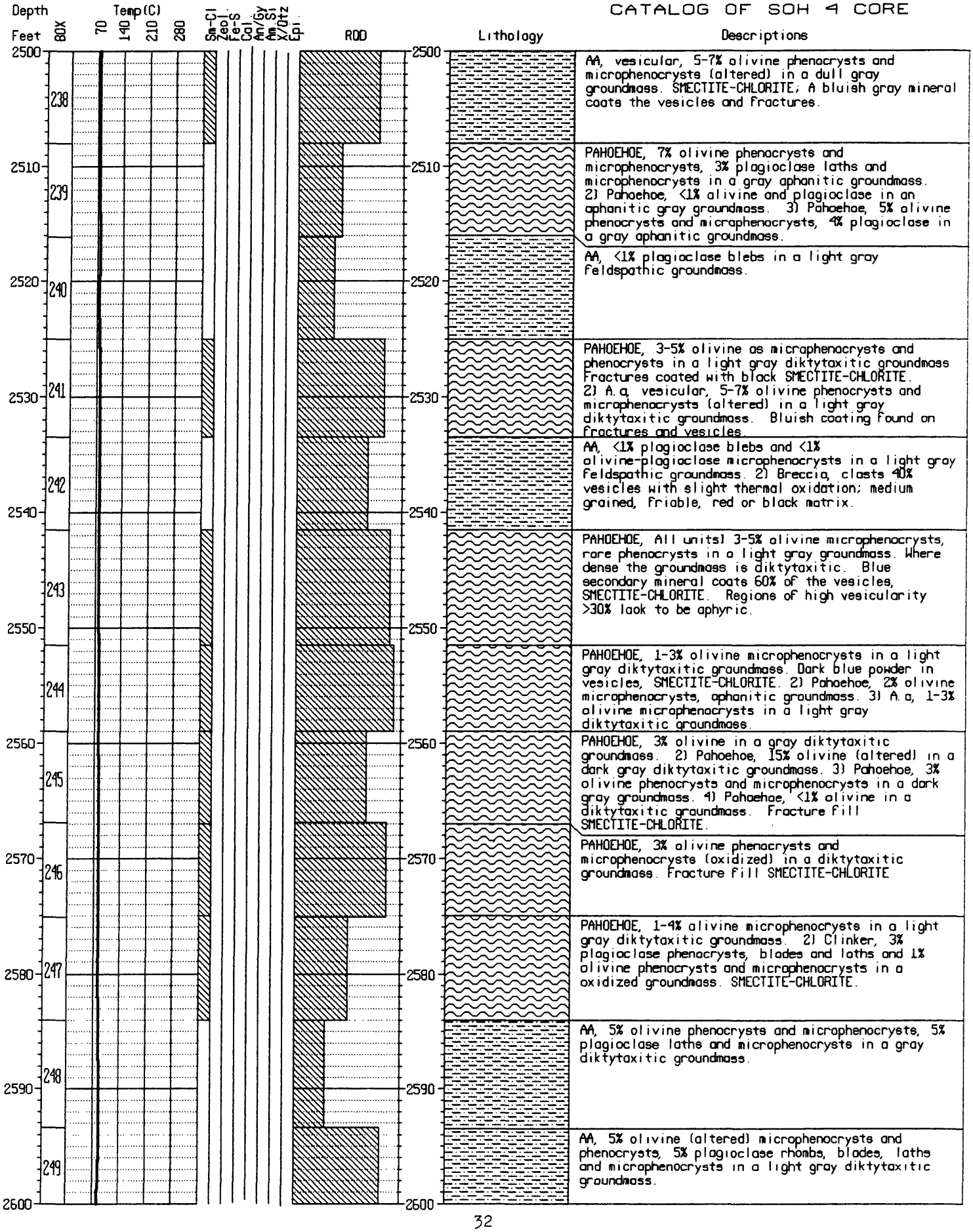

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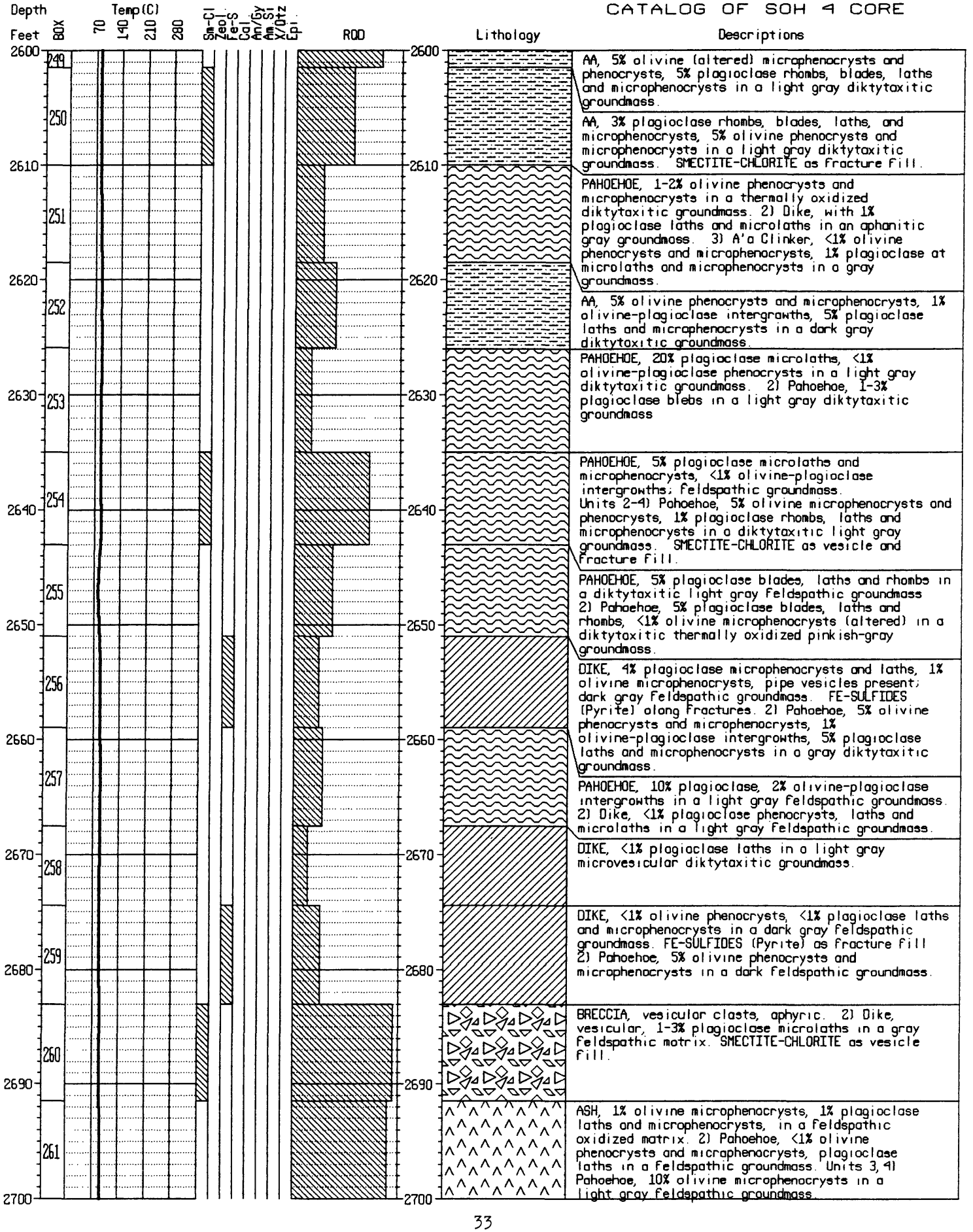

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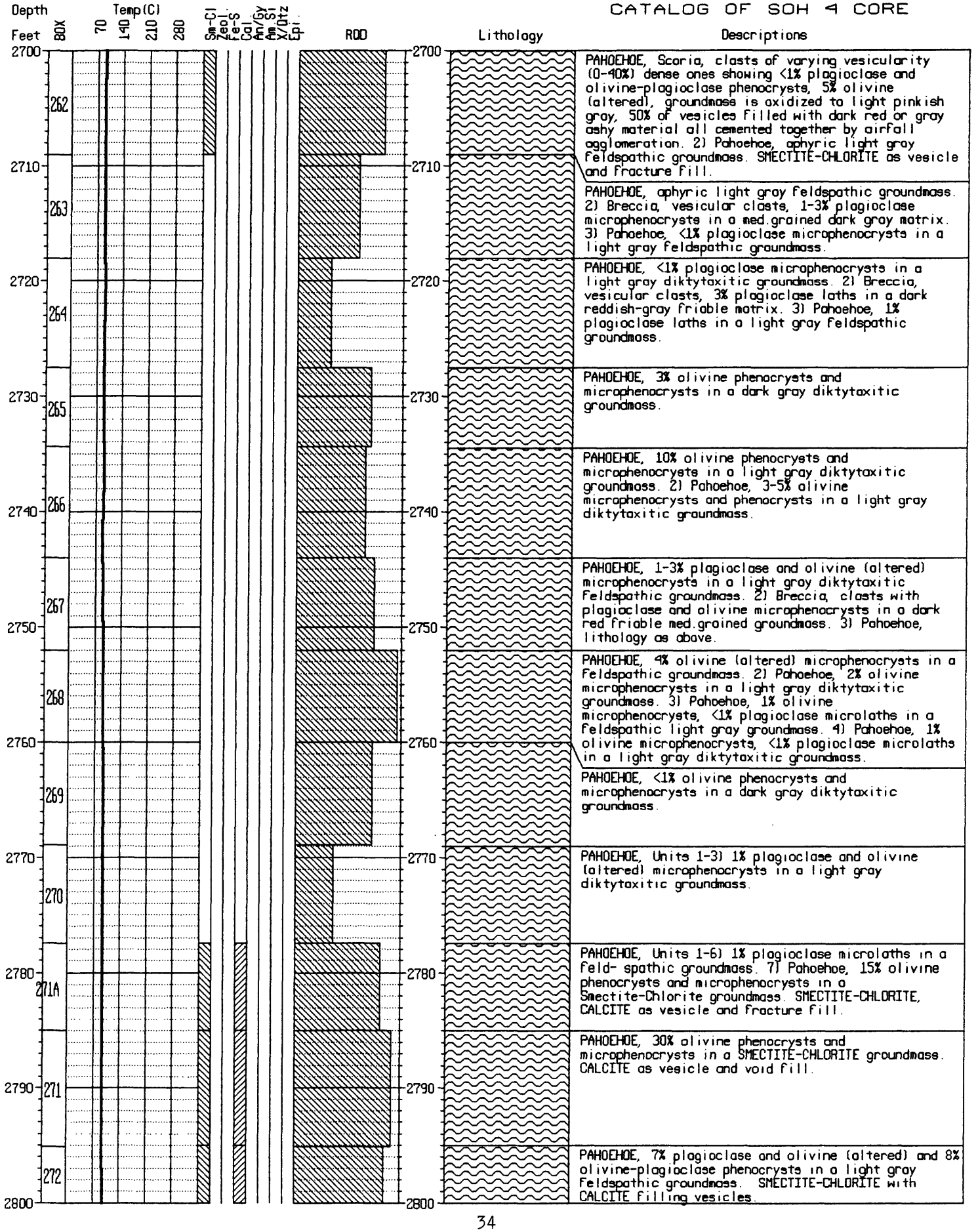

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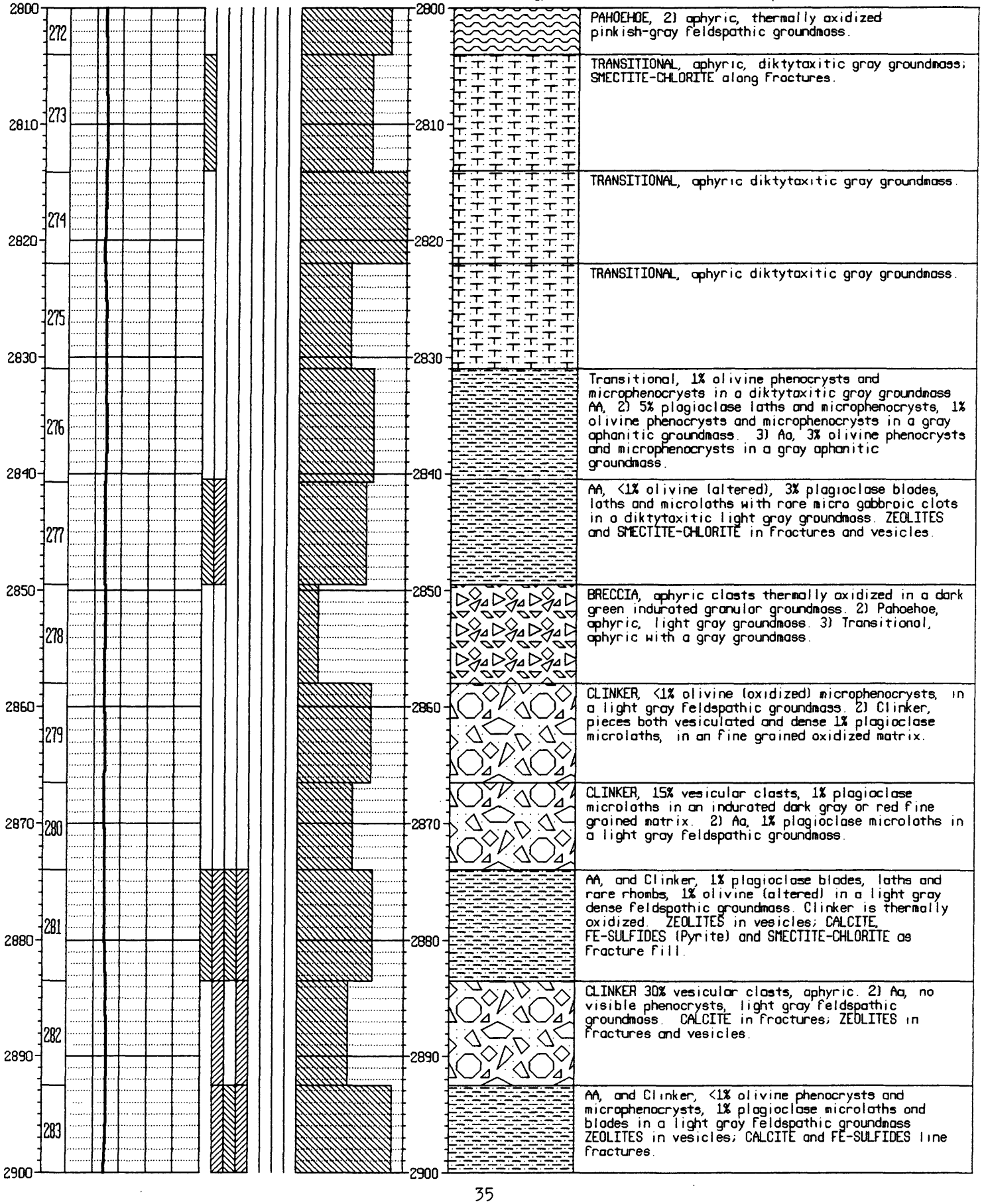

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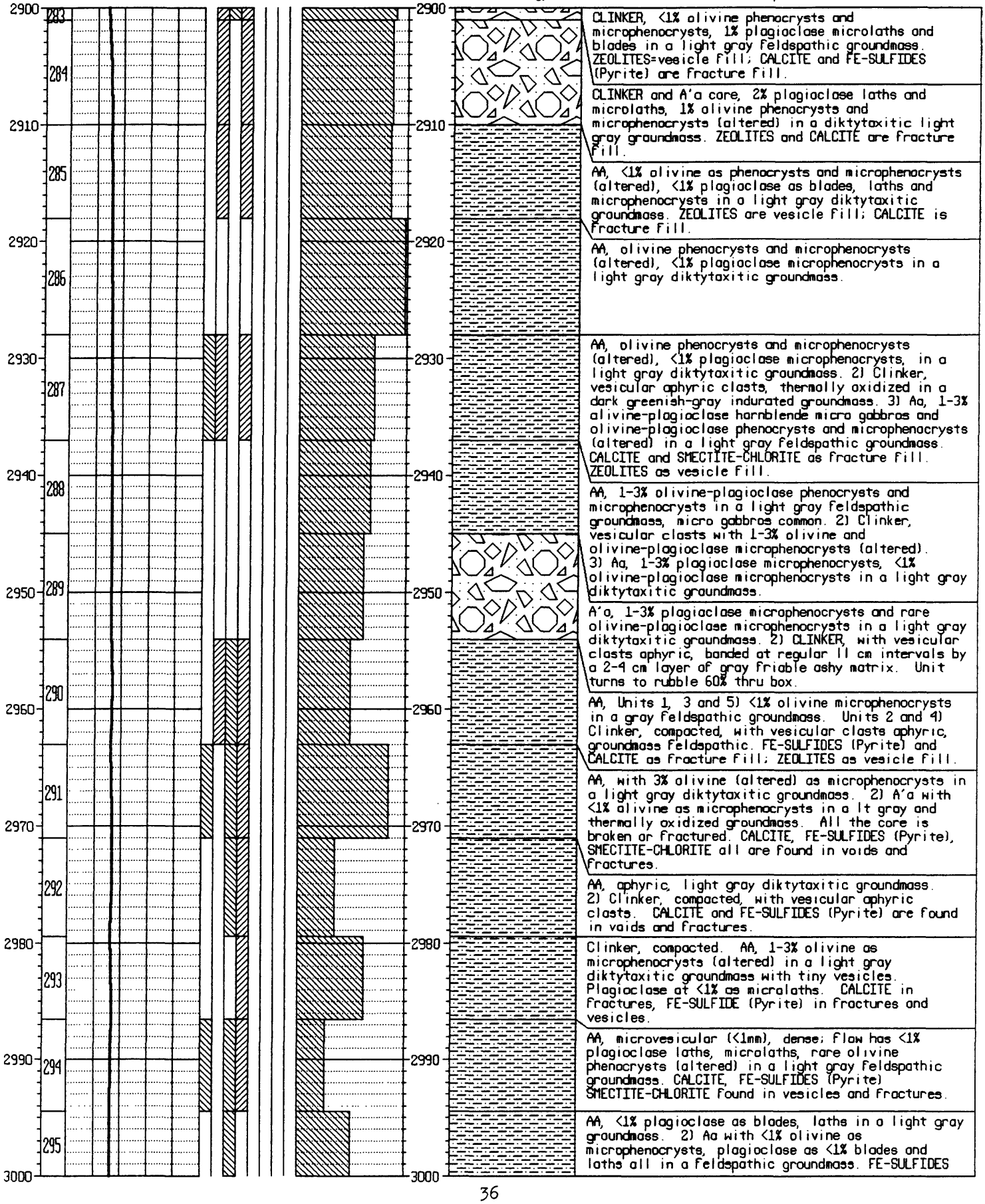
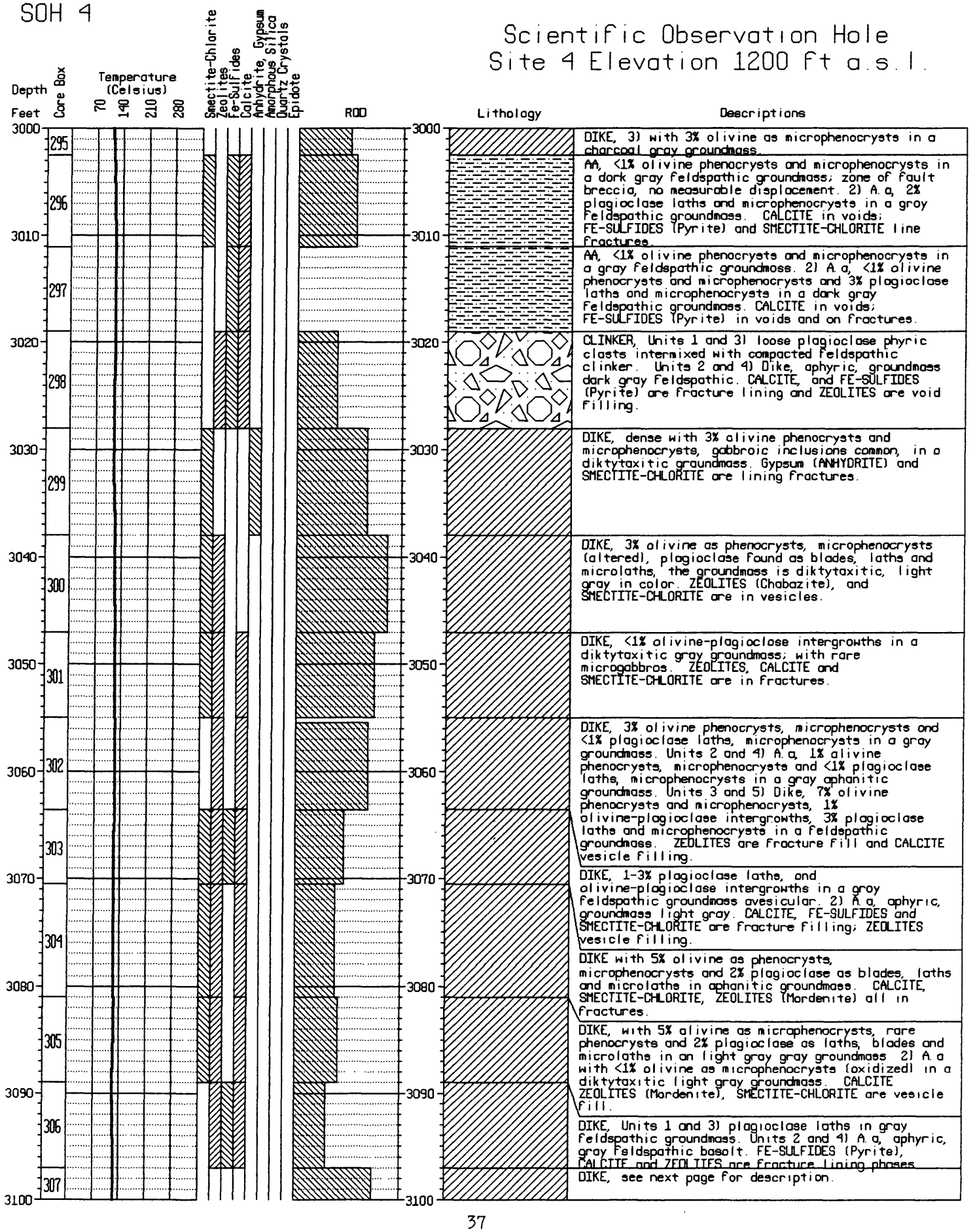


SOH 4

Scientific Observation Hole
Site 4 Elevation 1200 ft a.s.l.



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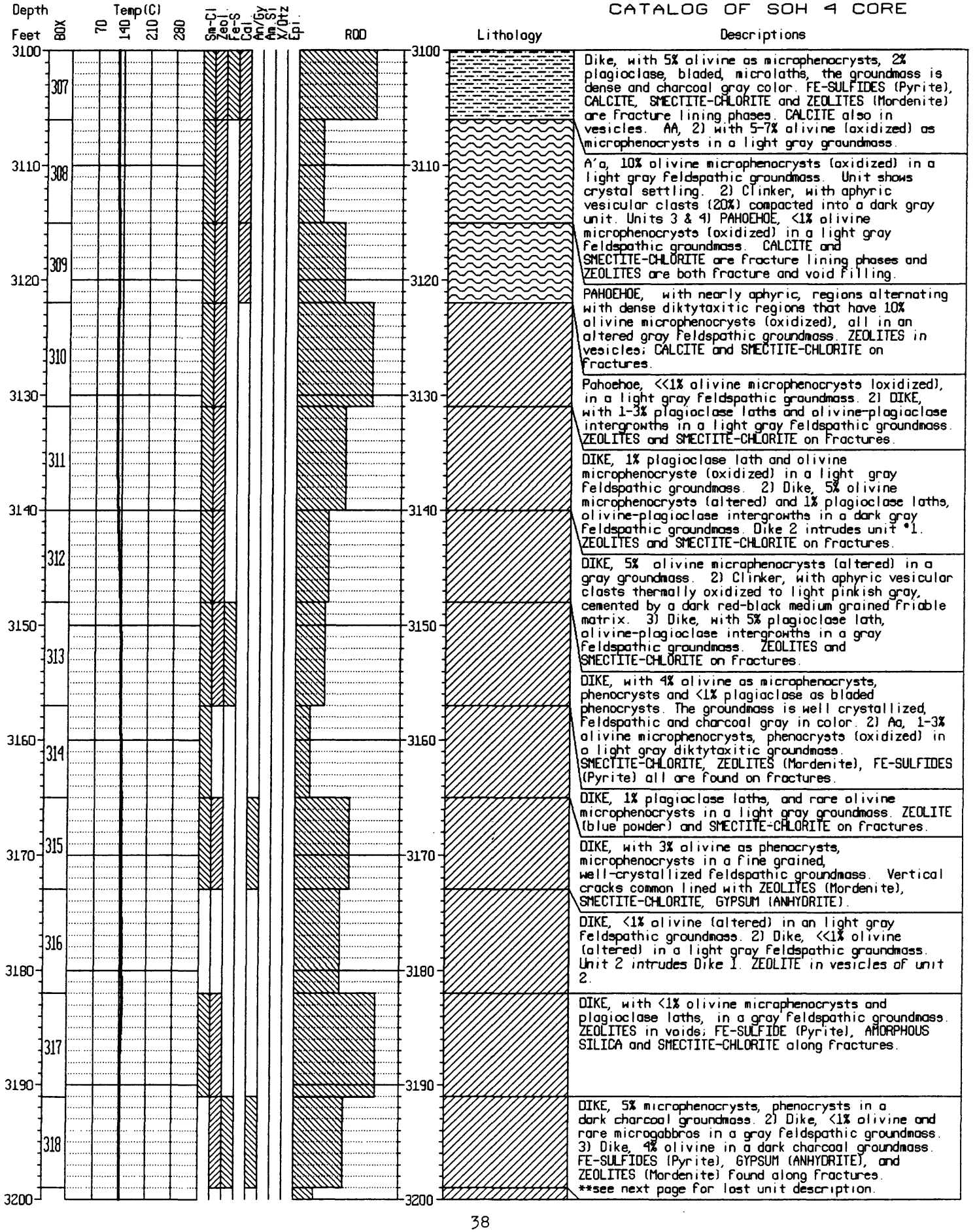

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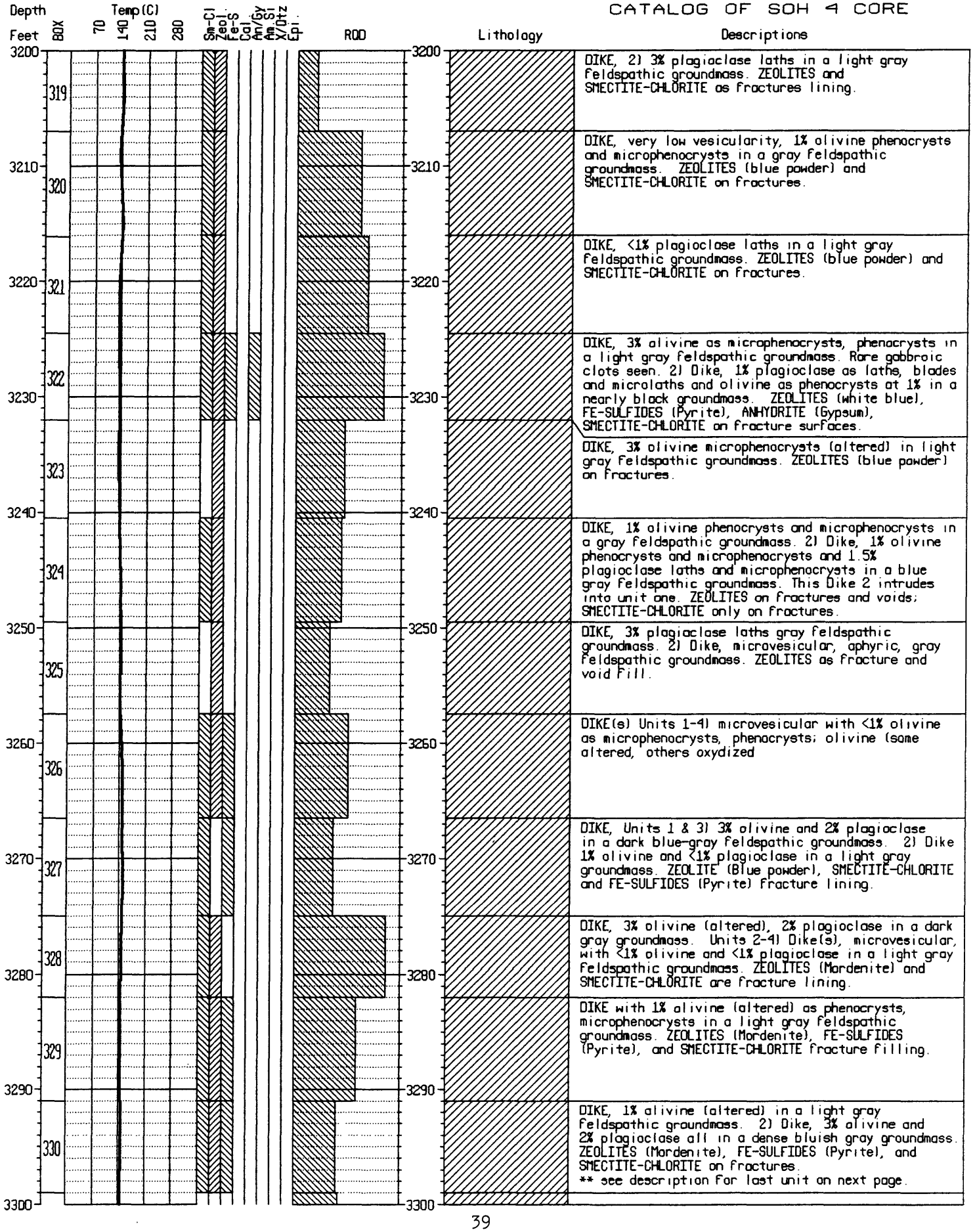

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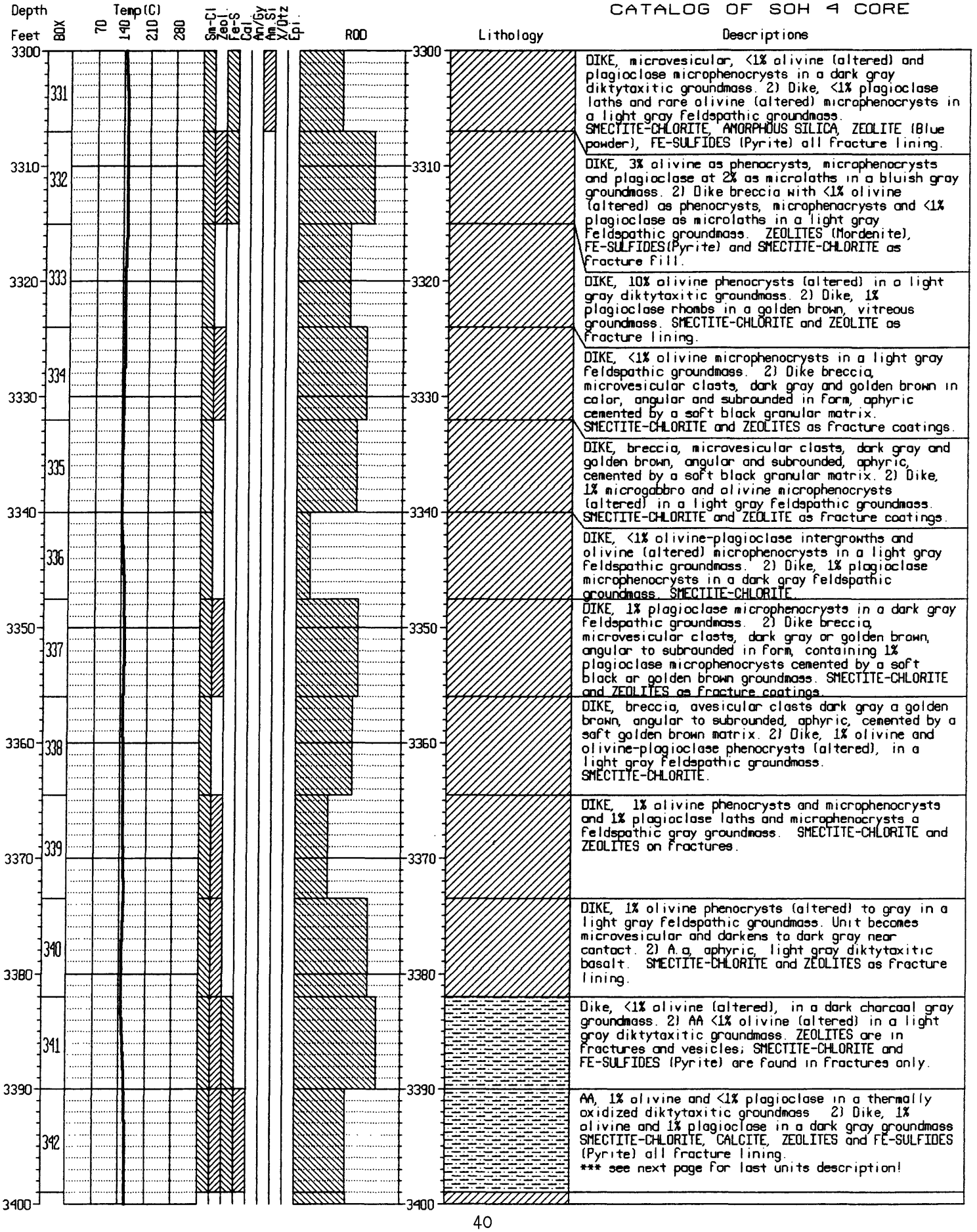

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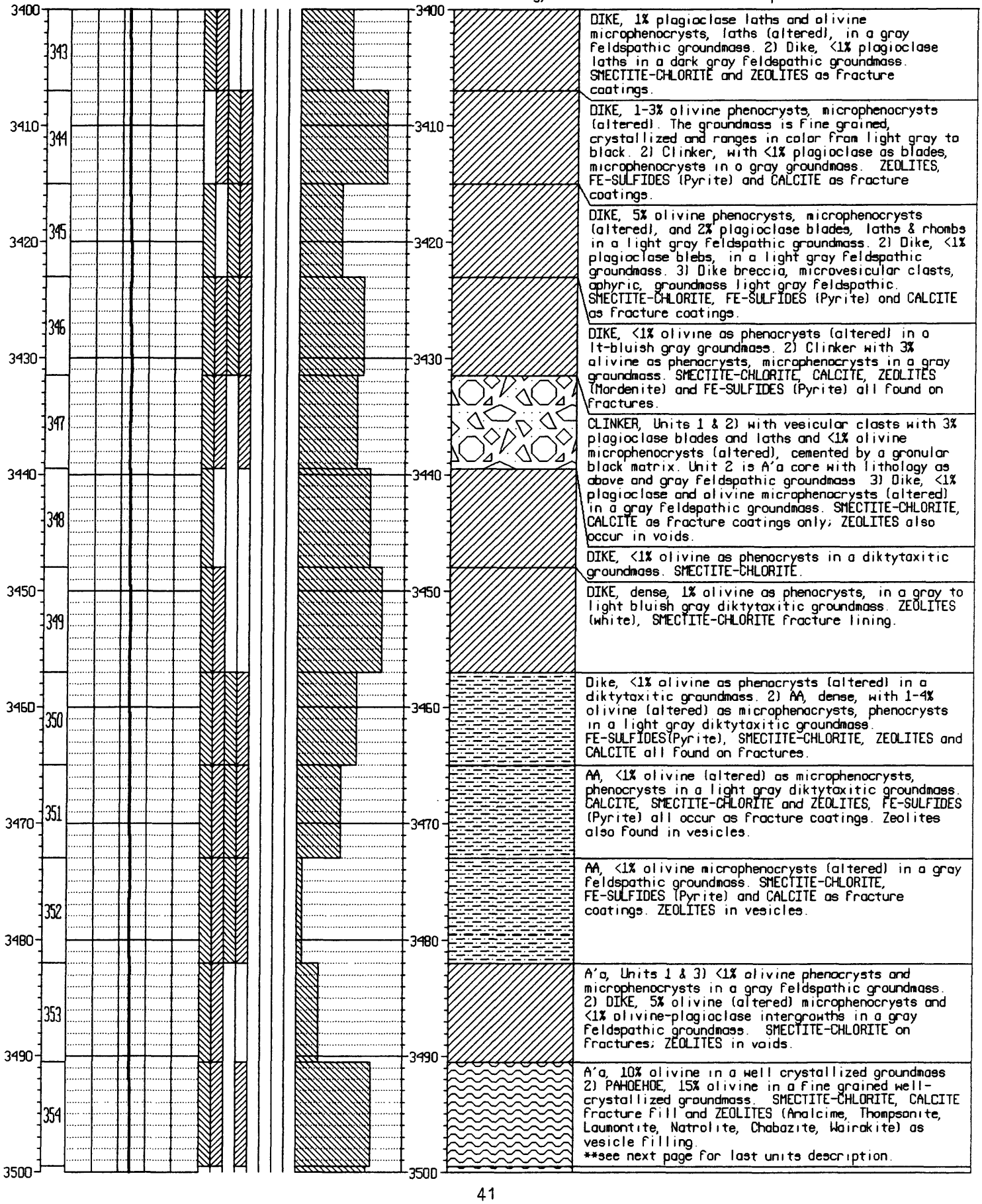

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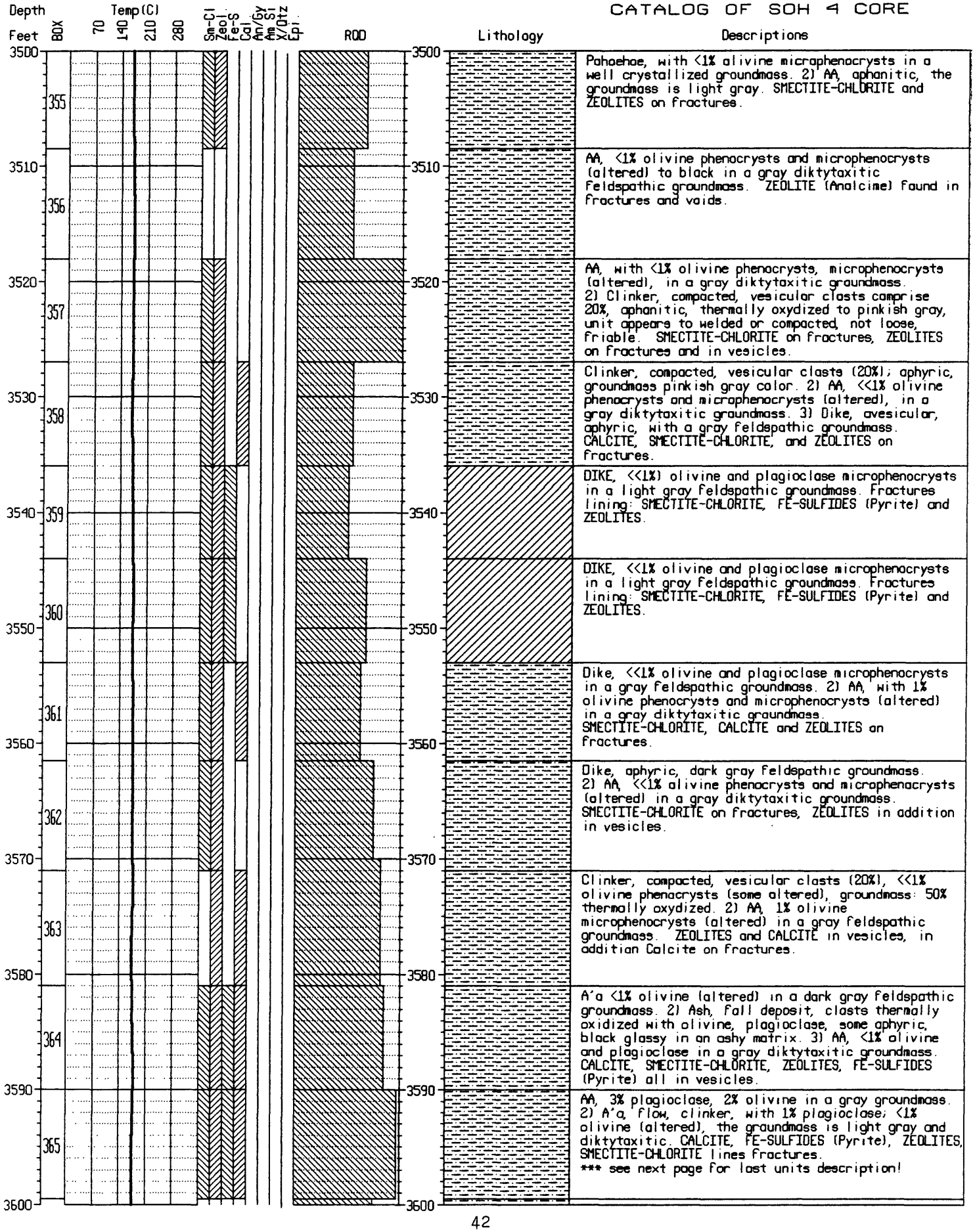

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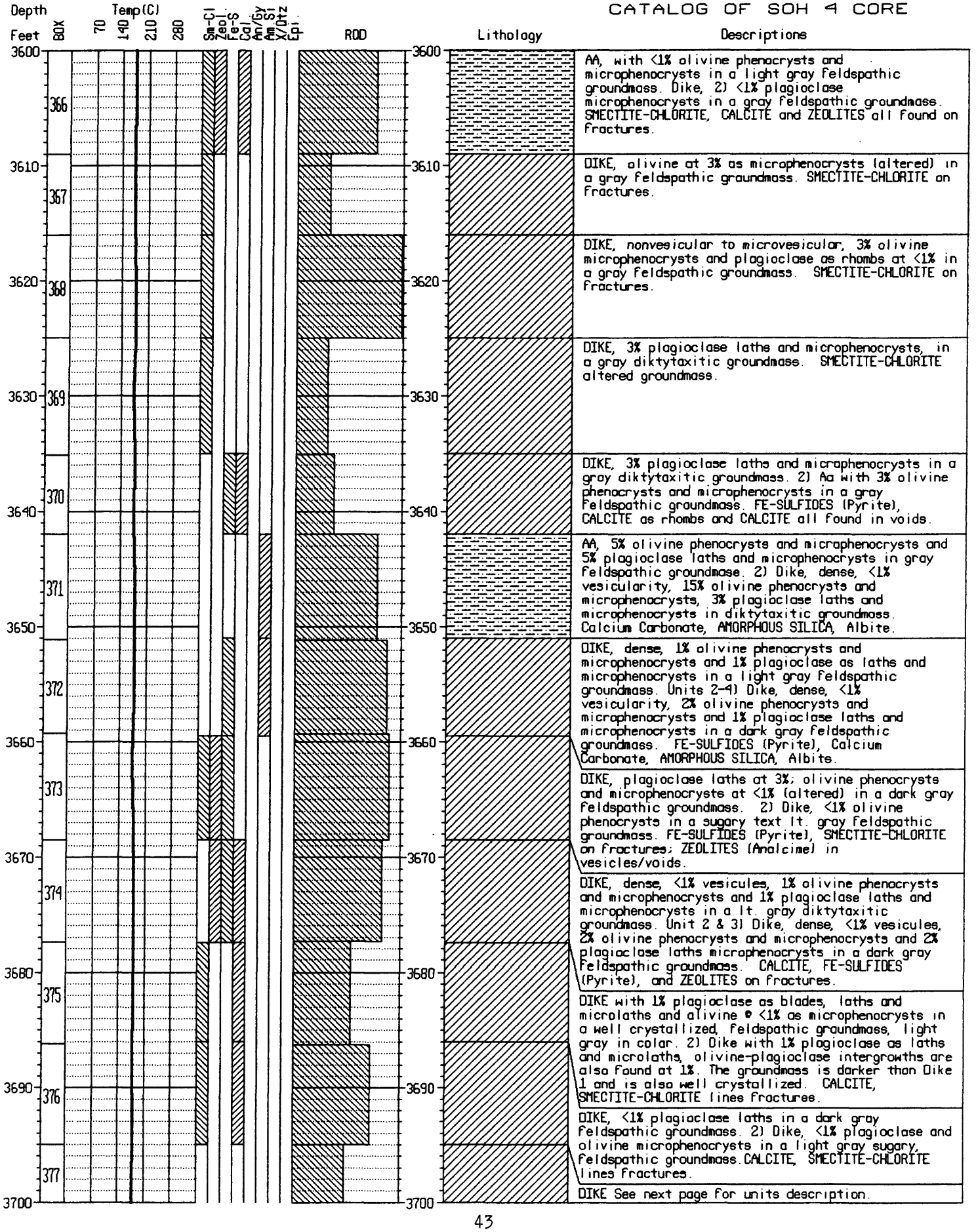

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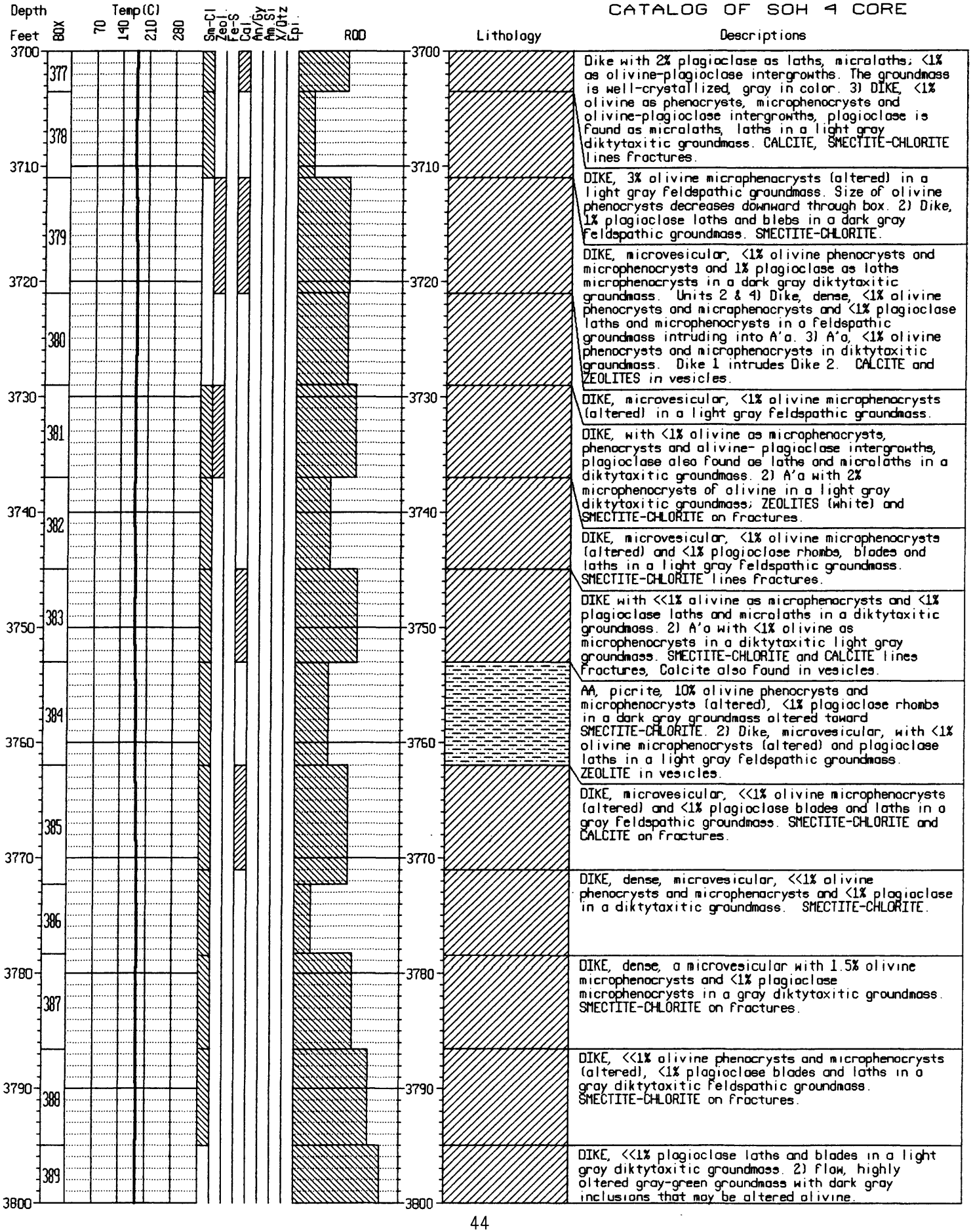

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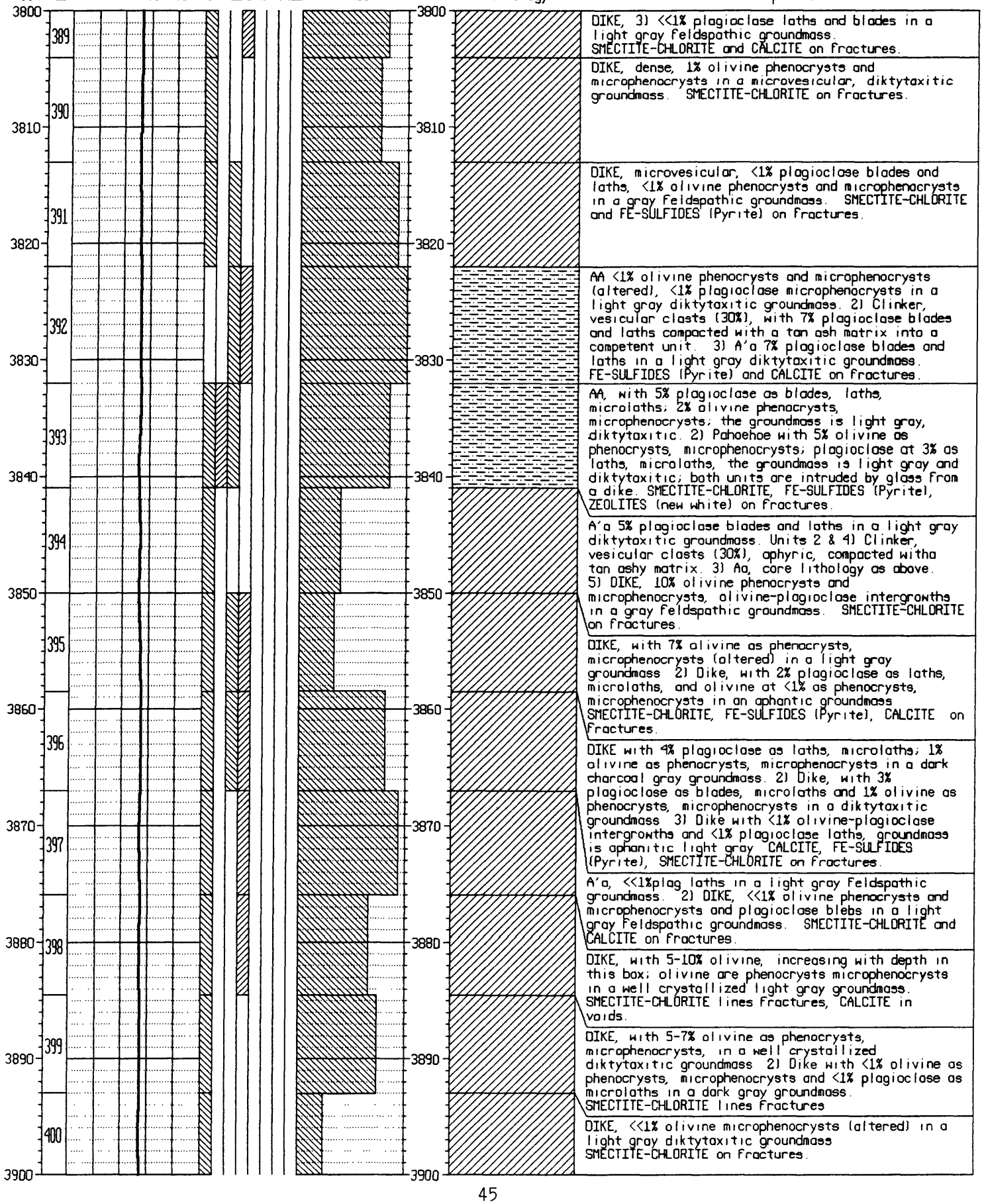

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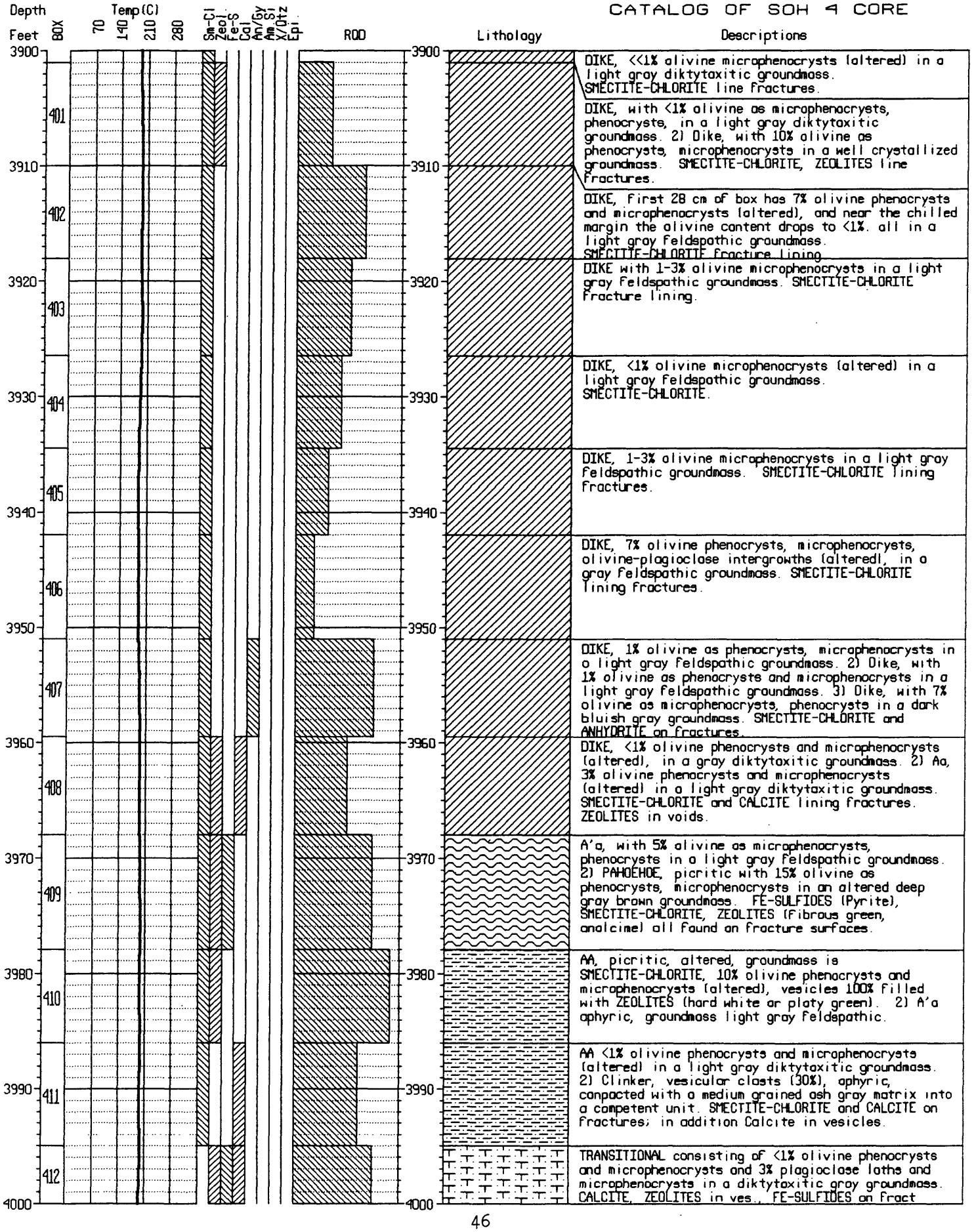
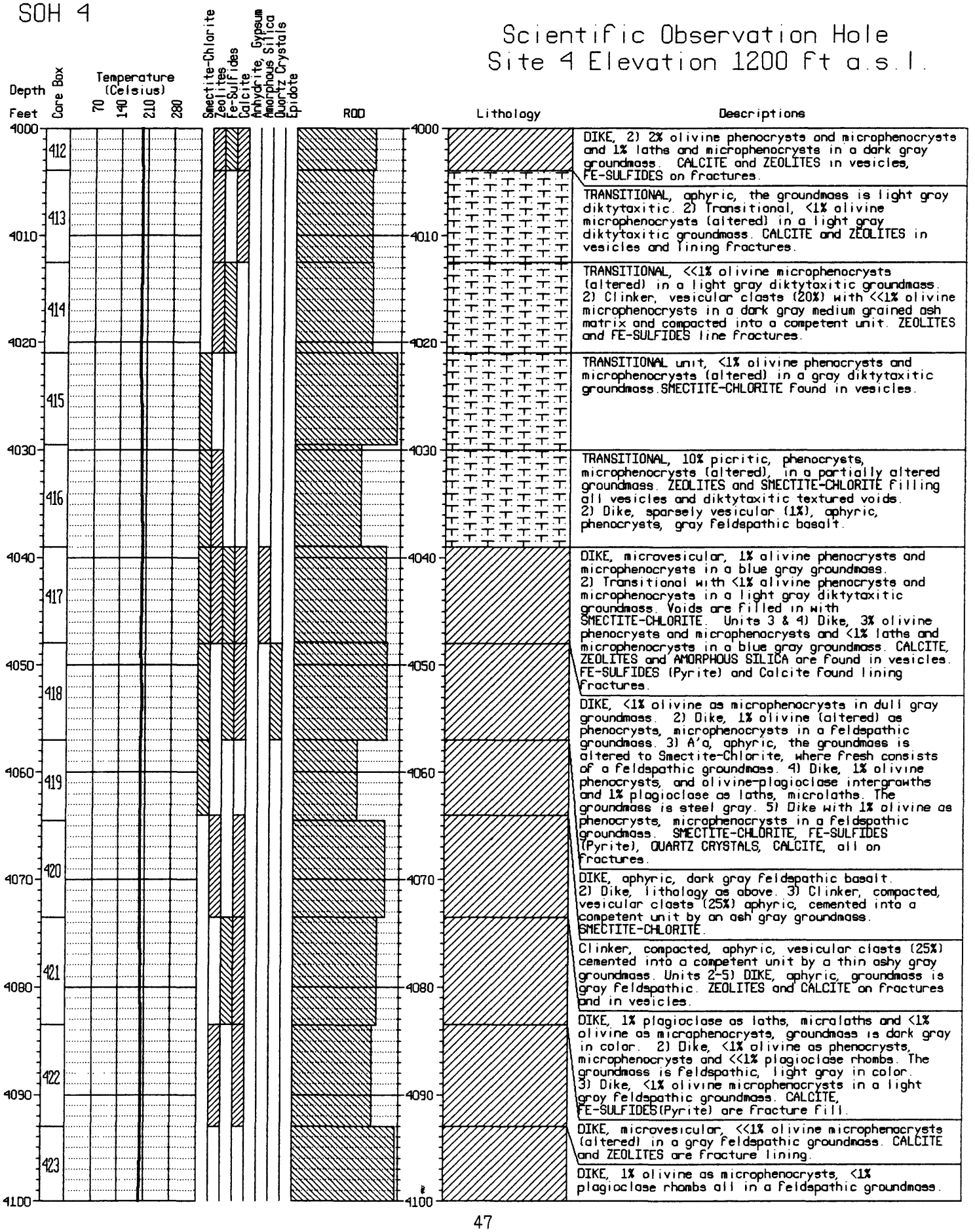


SOH 4

Scientific Observation Hole
Site 4 Elevation 1200 Ft a.s.l.



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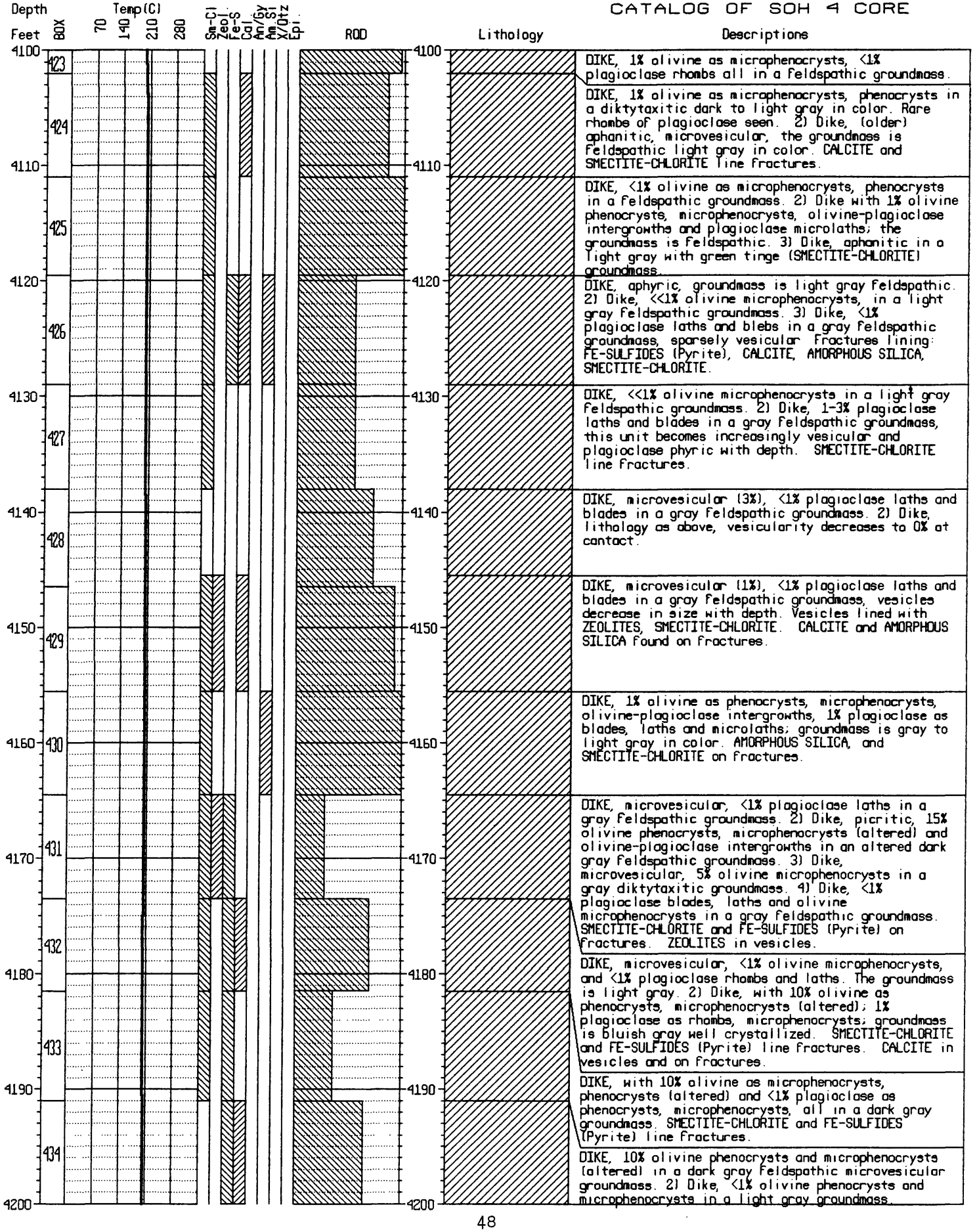

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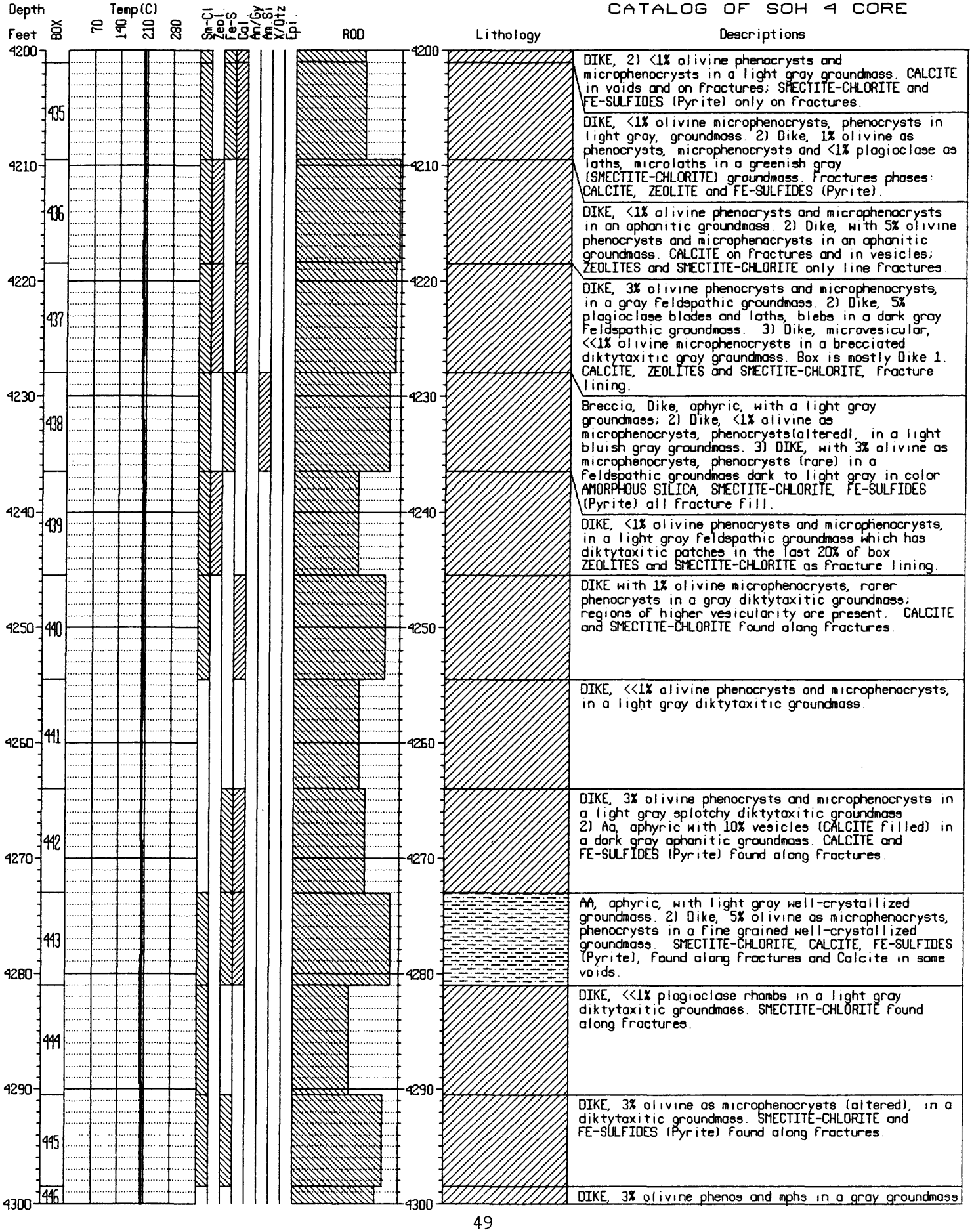

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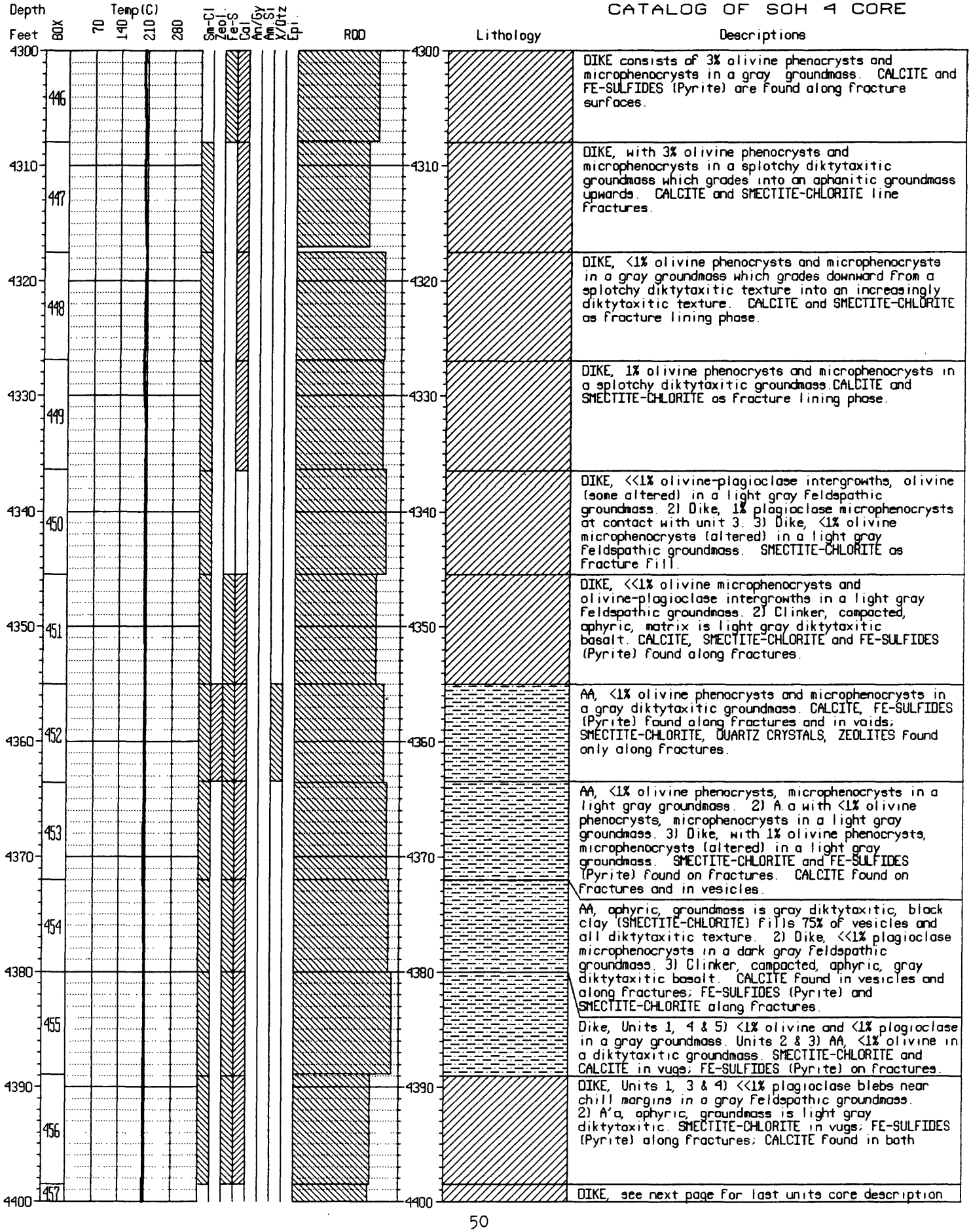

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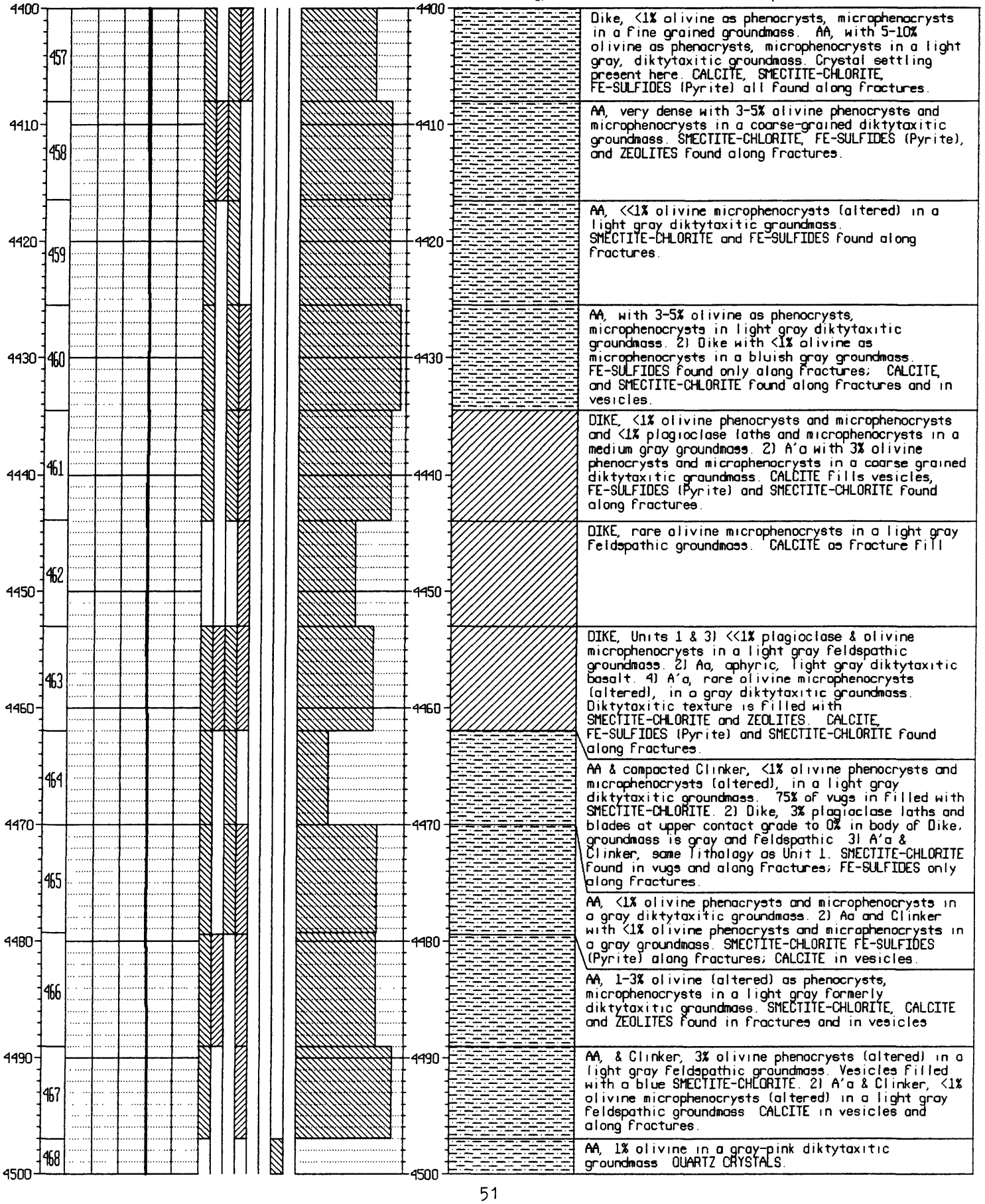

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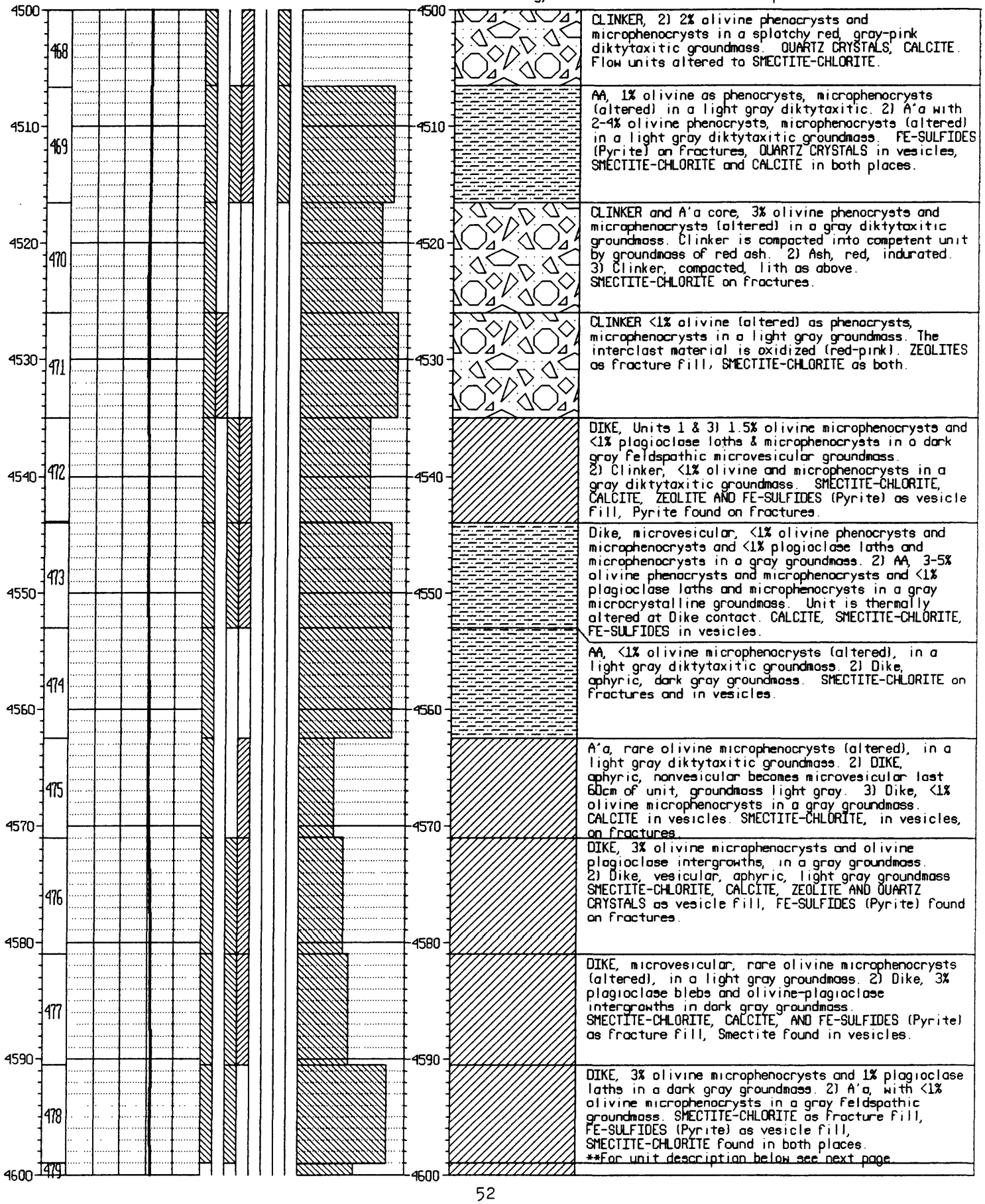

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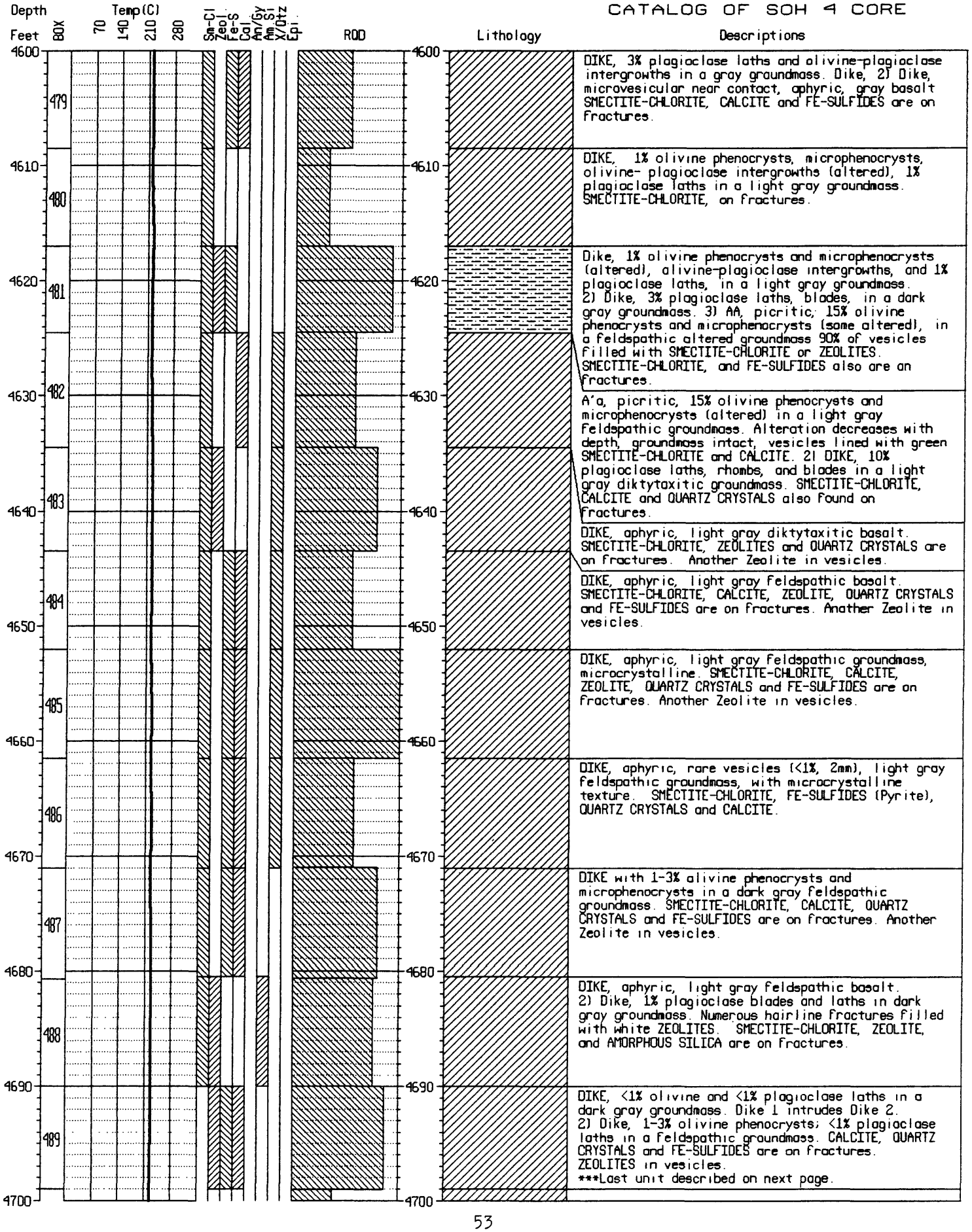

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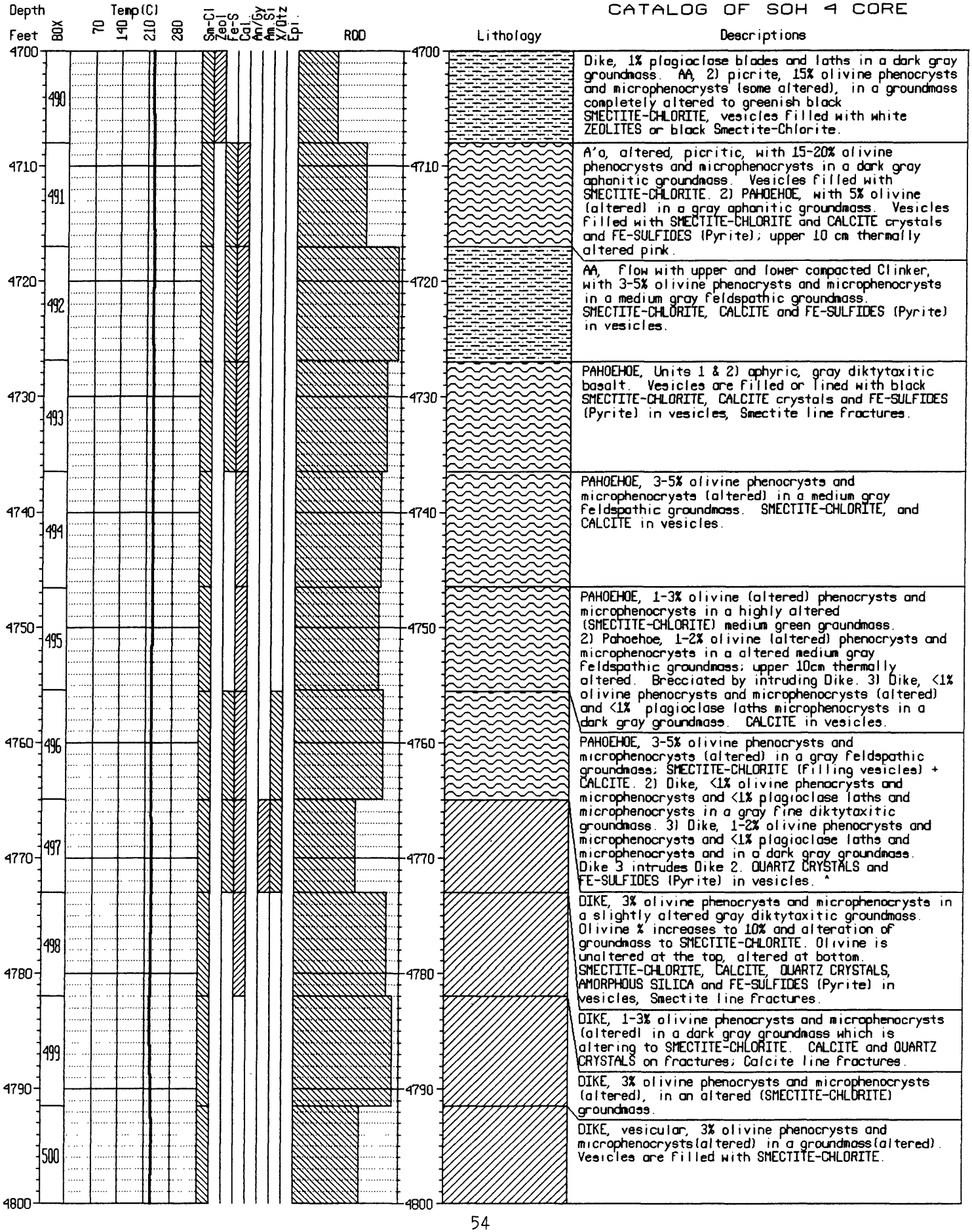

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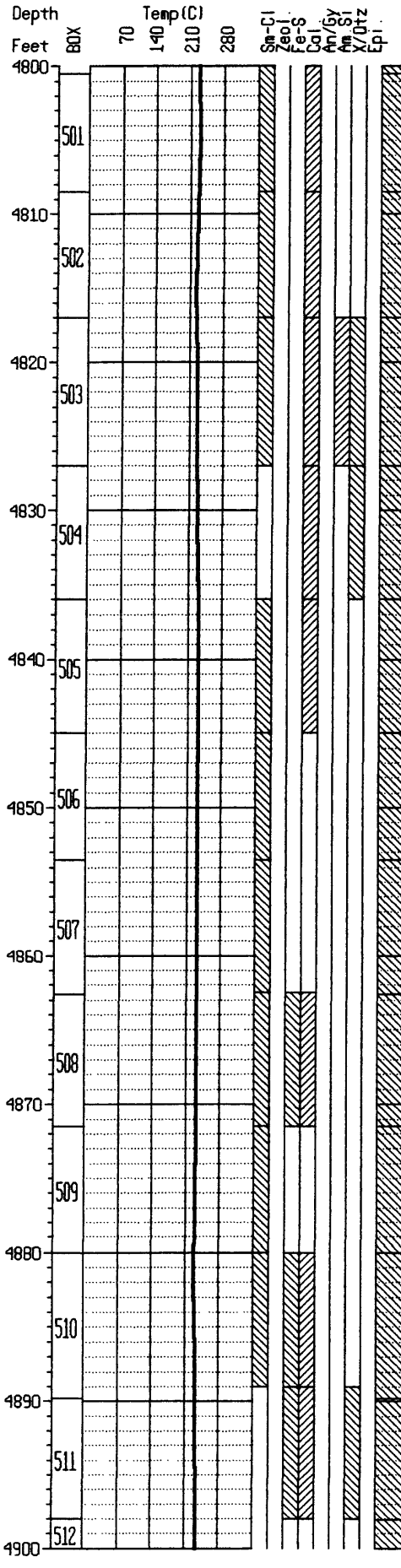
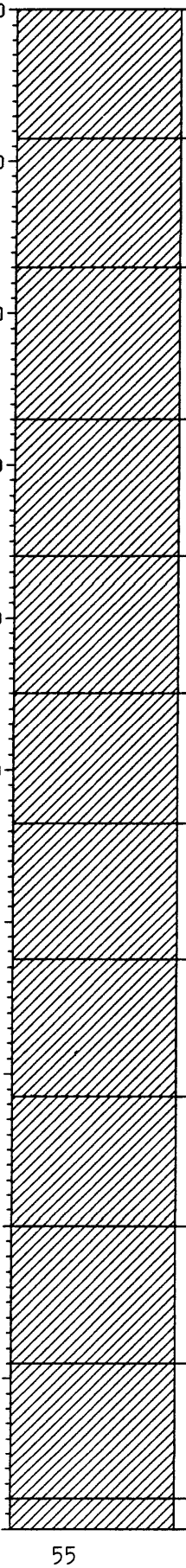




Descriptions

DIKE, vesicular, 3% olivine phenocrysts and microphenocrysts (altered) in an altered groundmass; SMECTITE-CHLORITE. The last 30cm of the box is unaltered. Vesicles are filled with SMECTITE-CHLORITE and CALCITE.

DIKE, 1st 16cm vesicular, rest nonvesicular, 1% olivine phenocrysts and microphenocrysts (altered) in a gray diktytaxitic groundmass (Smectite). SMECTITE-CHLORITE and CALCITE in vesicles.

DIKE, <1% olivine microphenocrysts (altered) in a gray diktytaxitic groundmass. 2) Dike, avesicular, 1% plagioclase microphenocrysts in a dark gray groundmass. SMECTITE-CHLORITE and AMORPHOUS SILICA lines fractures; CALCITE and QUARTZ CRYSTALS in vesicles.

DIKE, <1% olivine microphenocrysts (altered) in a gray diktytaxitic groundmass. 2) Dike, 1% plagioclase microphenocrysts in a dark gray groundmass. CALCITE and QUARTZ CRYSTALS in vesicles. Calcite also on fractures.

DIKE, rare plagioclase microphenocrysts in a gray groundmass. SMECTITE-CHLORITE and CALCITE lines fractures.

DIKE, aphyric, gray groundmass with unfilled hairline fractures. SMECTITE-CHLORITE lines fractures.

DIKE, with <1% olivine phenocrysts and microphenocrysts in a fine dark gray diktytaxitic groundmass altered to SMECTITE-CHLORITE.

DIKE, aphyric, gray groundmass; hairline fractures, filled with SMECTITE-CHLORITE, CALCITE and FE-SULFIDES (Pyrite).

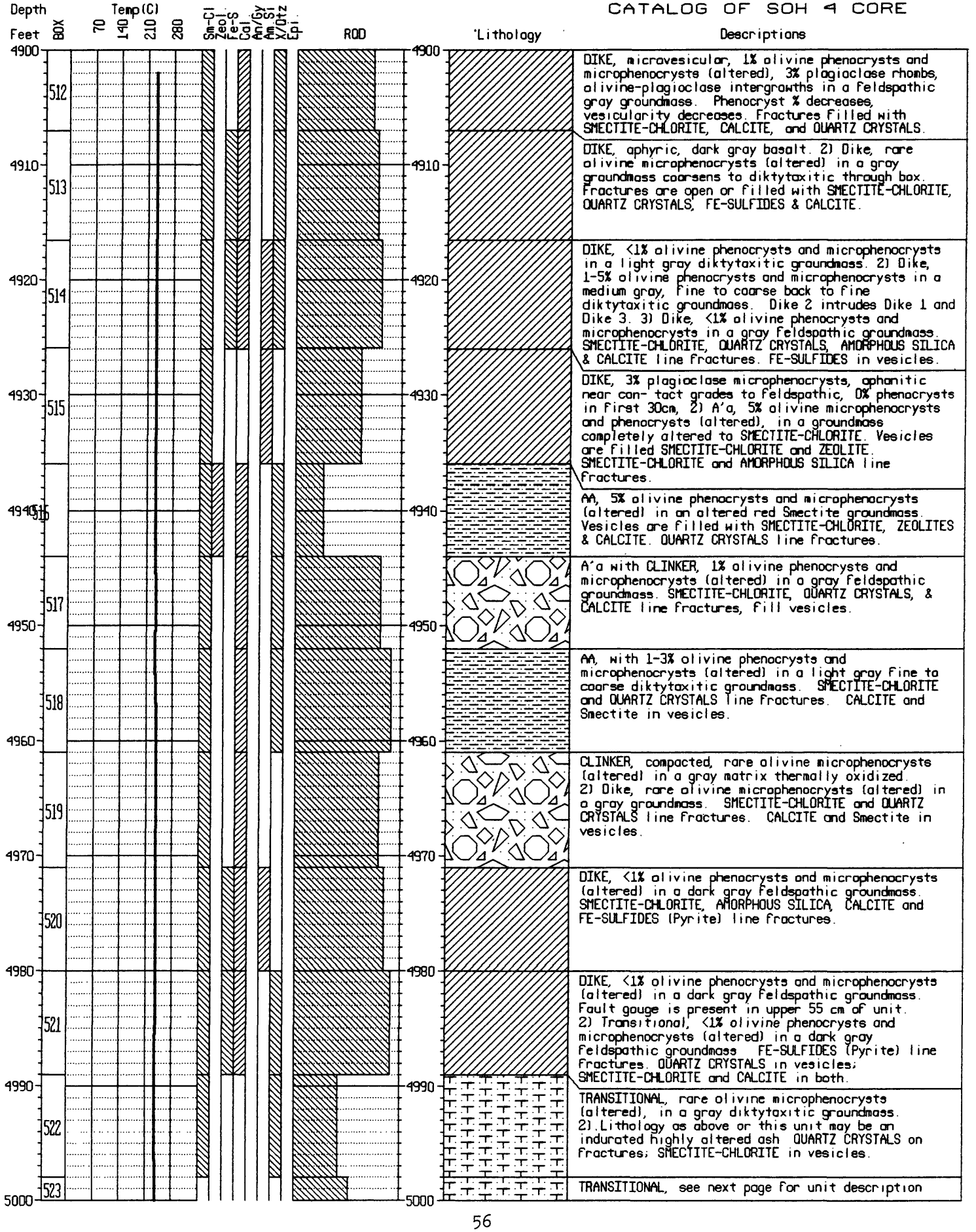
DIKE, with <1% olivine phenocrysts and microphenocrysts in a dark gray feldspathic groundmass. SMECTITE-CHLORITE lines fractures.

DIKE, aphyric, groundmass gray diktytaxitic. 2) Dike, <1% plagioclase blades and laths near chill margins, groundmass is dark gray; hairline fractures filled with CALCITE, SMECTITE-CHLORITE and FE-SULFIDES (Pyrite), numerous in unit #1, not as numerous in unit 2.

DIKE, <1% olivine phenocrysts and microphenocrysts in a medium gray feldspathic groundmass. 2) Dike, <1% olivine phenocrysts and microphenocrysts, in a microvesicular dark gray groundmass. CALCITE, QUARTZ CRYSTALS and FE-SULFIDES (Pyrite) along fractures.

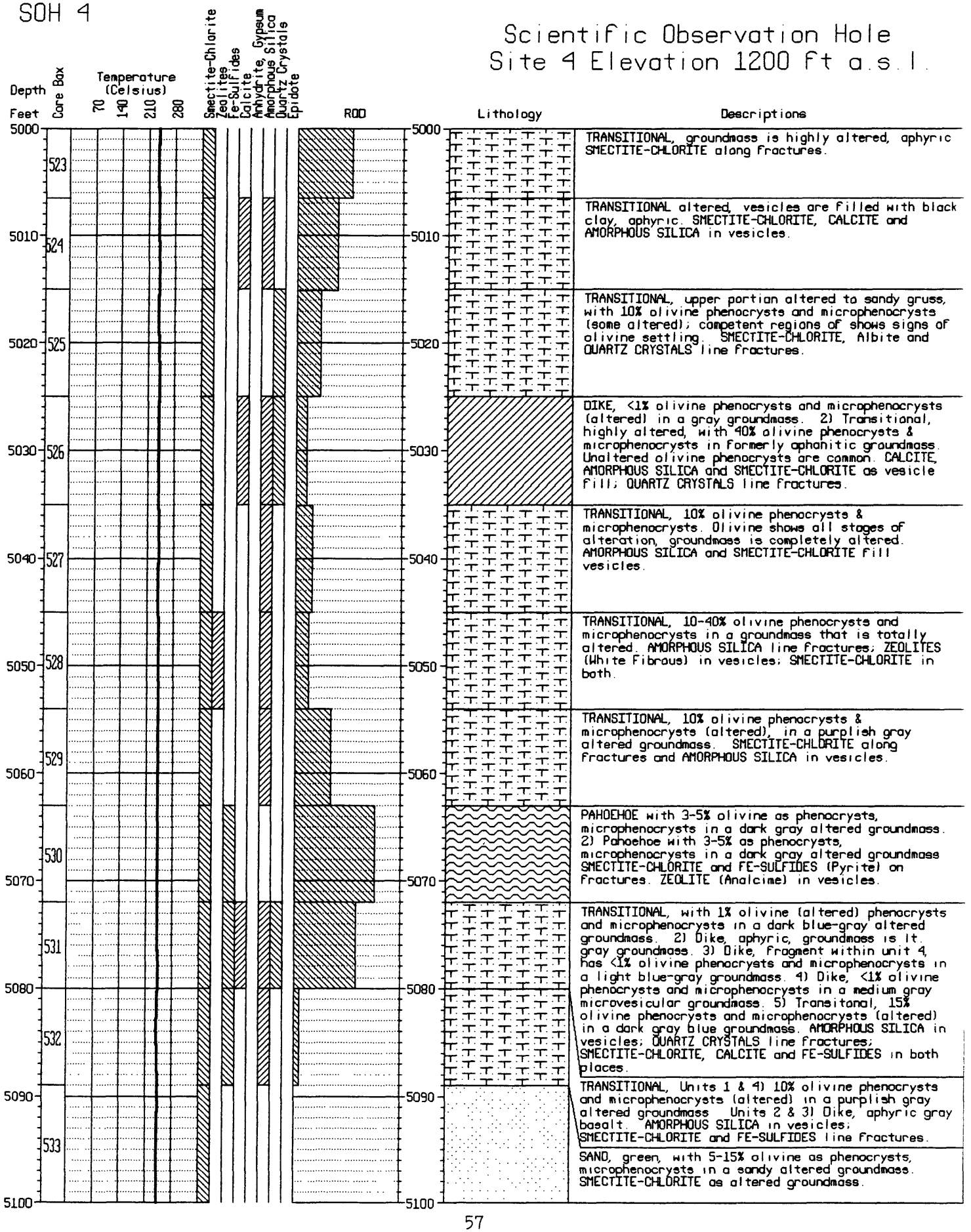
DIKE, see next page for description

CATALOG OF SOH 4 CORE



SOH 4

Scientific Observation Hole
Site 4 Elevation 1200 ft a.s.l.



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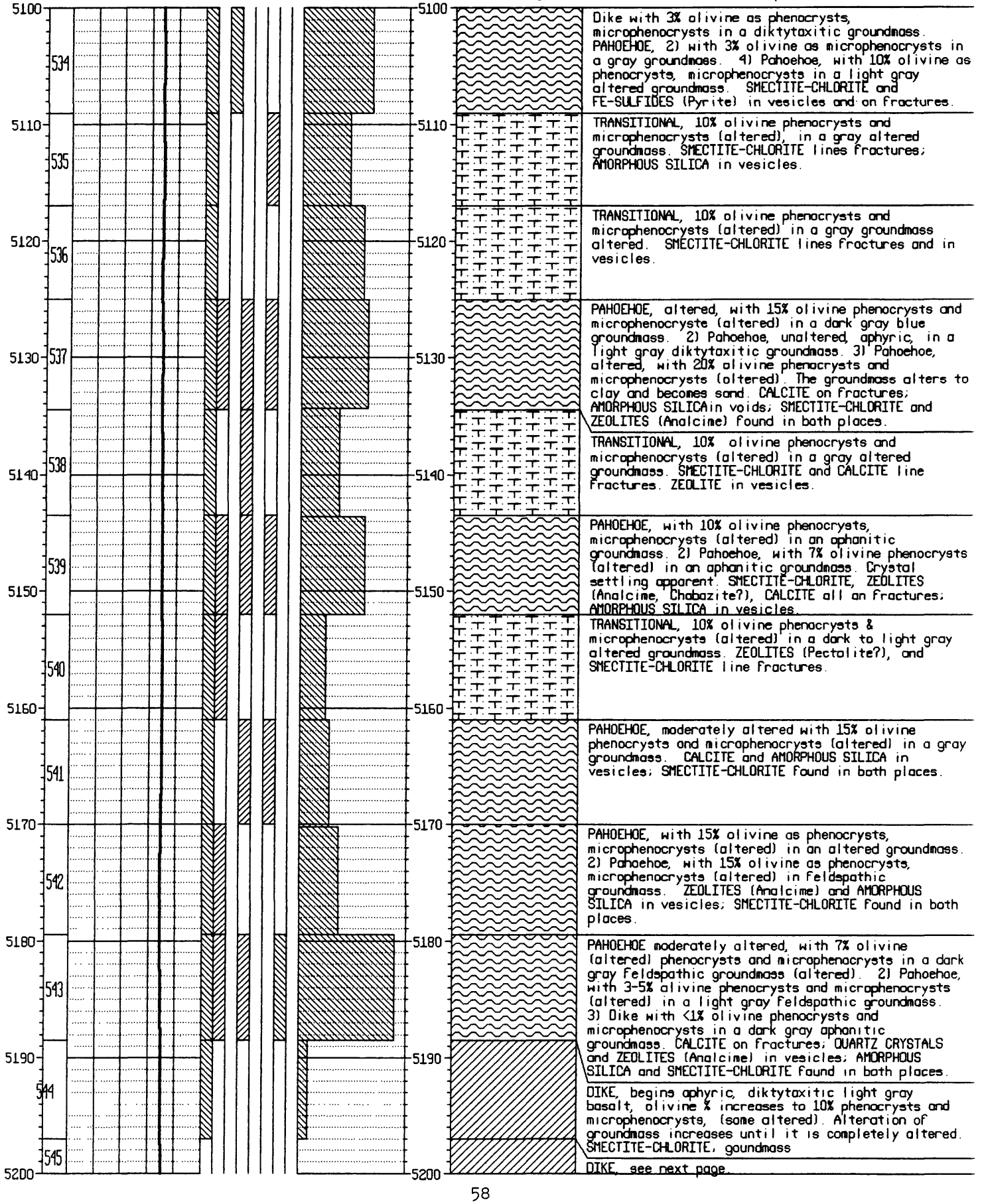

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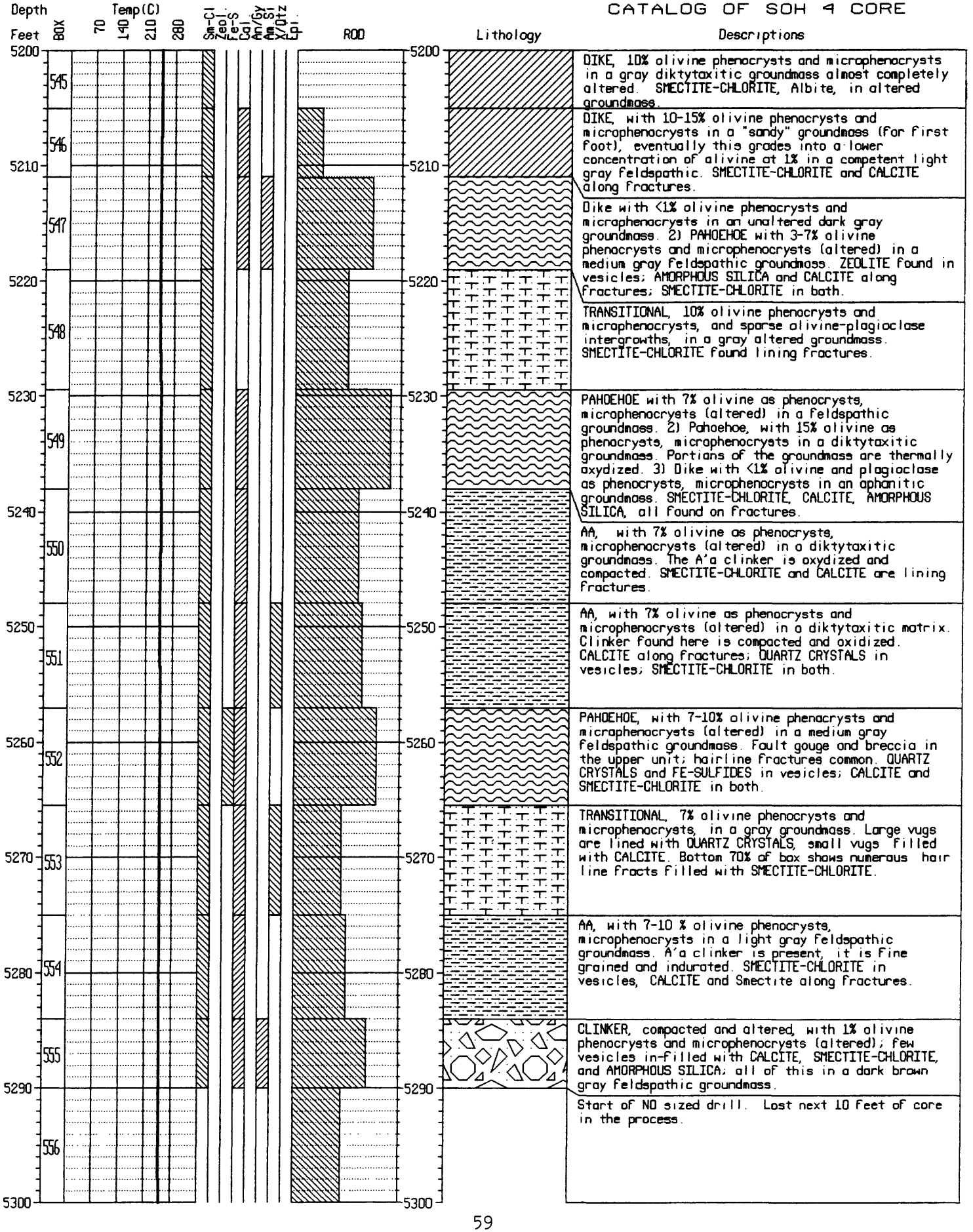

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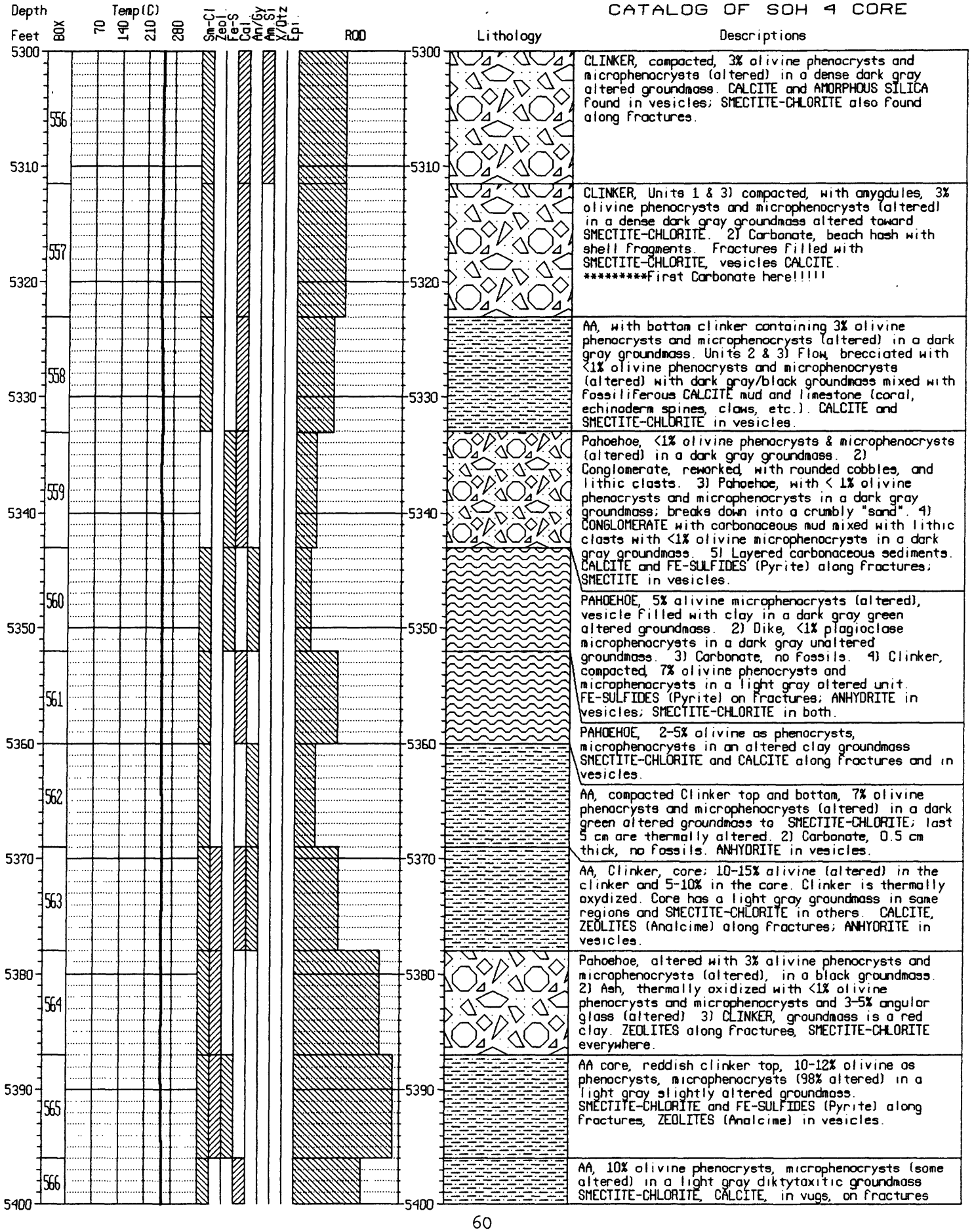

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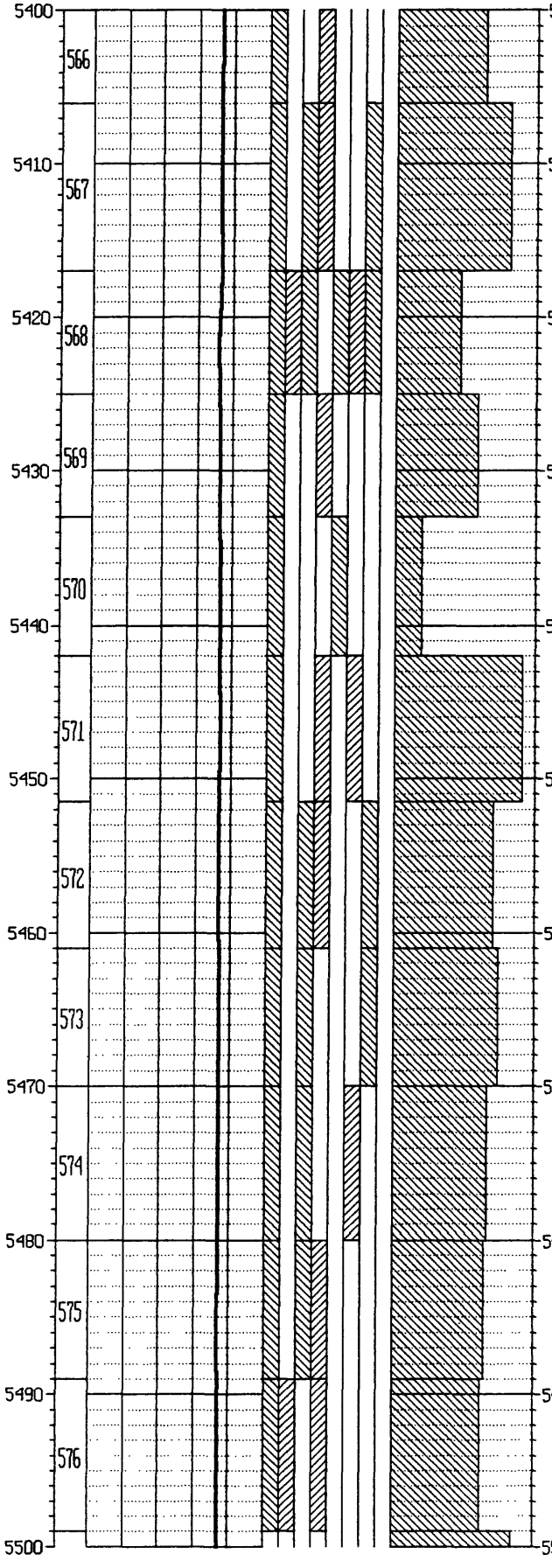


Lithology

Descriptions

AA, with 10% olivine phenocrysts, microphenocrysts (some altered) in a light gray diktytoxitic groundmass. SMECTITE-CHLORITE, CALCITE in vugs and lining fractures.

AA, picritic, 7-15% olivine (altered) phenocrysts and microphenocrysts, hairline fractures common; gabbroic inclusions common in a gray feldspathic groundmass 2) Dike, with < 1% plagioclase microphenocrysts and laths in a medium gray diktytoxitic groundmass. QUARTZ CRYSTALS in vesicles; SMECTITE-CHLORITE, CALCITE and FE-SULFIDES (Pyrite) lining fractures.

Dike, rare plagioclase microphenocrysts in a gray diktytoxitic groundmass. 2) A'a, 7% olivine phenocrysts and microphenocrysts (altered), groundmass diktytoxitic brecciated near at contact. 3) AA, altered, alteration increases with depth. QUARTZ CRYSTALS and ANHYDRITE in vesicles; SMECTITE-CHLORITE, AMORPHOUS SILICA and FE-SULFIDES (Pyrite) lining fractures. ZEOLITES in both.

AA, picritic, 15% olivine as phenocrysts, microphenocrysts (altered) in an altered groundmass SMECTITE-CHLORITE and CALCITE in vesicles and on fractures.

AA, altered, olivine (altered) and SMECTITE-CHLORITE filled vesicles 20% at top of box decreases to 10% at bottom, all in a light gray SMECTITE-CHLORITE groundmass. ANHYDRITE on fractures.

PAHOEHOE, picritic, partly altered, 15-20% olivine phenocrysts and microphenocrysts (altered), vesicles filled with SMECTITE-CHLORITE, hair line fractures common in a diktytoxitic medium dark gray groundmass. AMORPHOUS SILICA, CALCITE lining fractures. SMECTITE-CHLORITE in both.

Pahoehoe, partly altered, picritic, olivine (altered) in a medium dark gray groundmass. 2) DIKE, with <1% olivine phenocrysts and microphenocrysts and <1% plagioclase microlaths and microphenocrysts in a gray diktytoxitic groundmass. Hairline fractures increasing upward; upper half of the unit is brecciated. 3) Dike, glassy, aphyric, in a golden dark brown groundmass. Dike 3 intrudes into Dike 2. QUARTZ CRYSTALS, SMECTITE-CHLORITE, AMORPHOUS SILICA, CALCITE, and FE-SULFIDES (Pyrite) lining fractures.

DIKE, brecciated, groundmass gray diktytoxitic. 2) Pahoehoe, altered, 7% olivine phenocrysts and microphenocrysts (altered) in a gray altered groundmass. 3) Dike, <<1% plagioclase microphenocrysts, groundmass is diktytoxitic gray QUARTZ CRYSTALS and FE-SULFIDES (Pyrite) lining fractures. SMECTITE-CHLORITE in both.

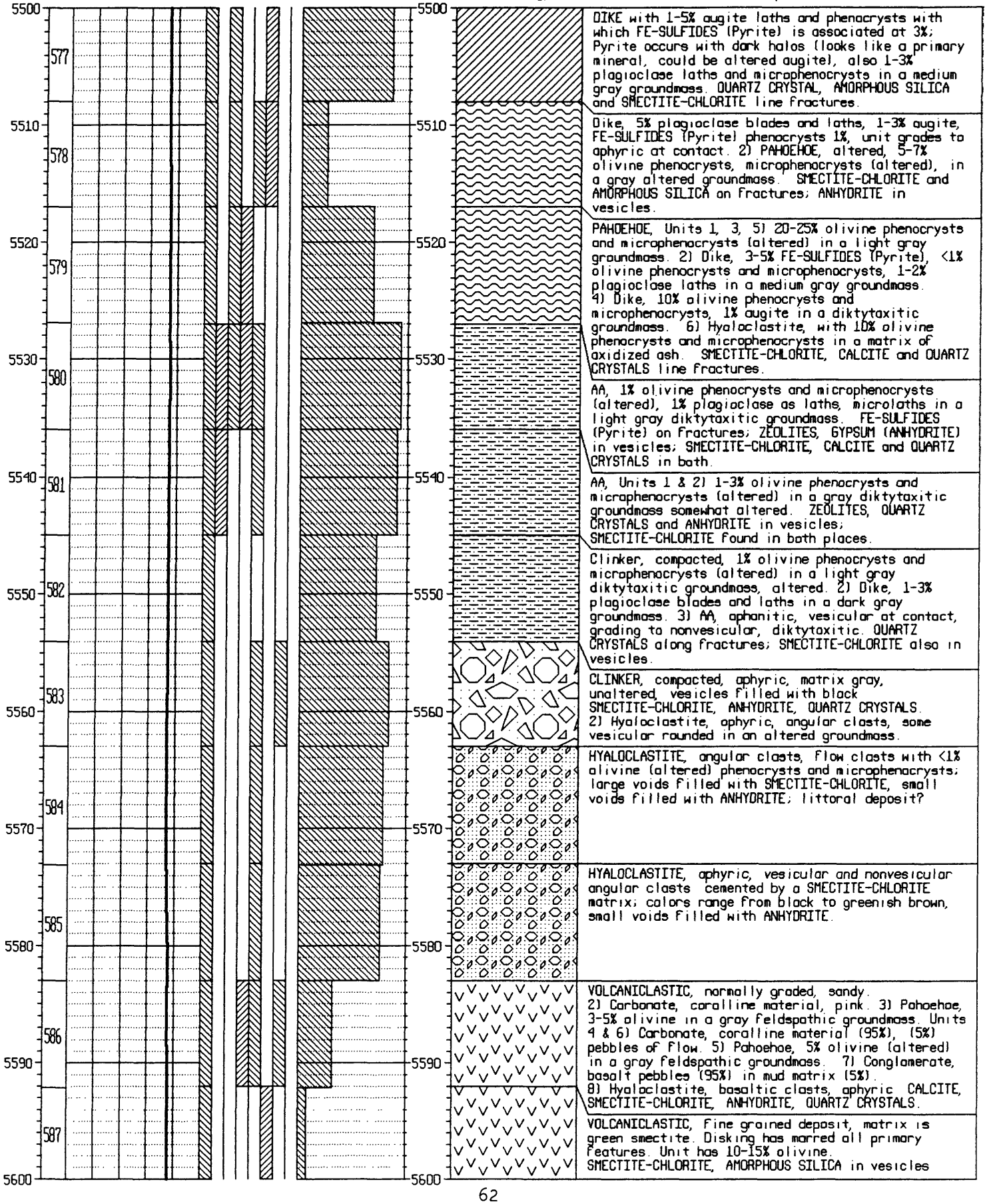
DIKE, Units 1 & 3) diktytoxitic, gray colored groundmass altering to SMECTITE-CHLORITE. 2) Dike, <1% plagioclase microphenocrysts, gray groundmass. 4) Dike, partly brecciated, aphyric gray basalt 5) Dike, aphyric, groundmass is diktytoxitic gray SMECTITE-CHLORITE, AMORPHOUS SILICA and FE-SULFIDES (Pyrite) lining fractures.

AA, picritic with 10-15% olivine as phenocrysts, microphenocrysts in a light gray originally diktytoxitic groundmass; now the groundmass is 15-40% altered to SMECTITE-CHLORITE. CALCITE, FE-SULFIDES (Pyrite) along fractures.

AA, picritic, 10-15% olivine (altered) in a partially altered feldspathic groundmass. 2) Dike, with <1% olivine phenocrysts, microphenocrysts and <1% plagioclase as laths in a feldspathic groundmass. SMECTITE-CHLORITE, CALCITE, QUARTZ CRYSTALS, ZEOLITES (green fiberous) all along fractures.

FOR DESCRIPTION OF LAST UNIT SEE NEXT PAGE.

CATALOG OF SOH 4 CORE



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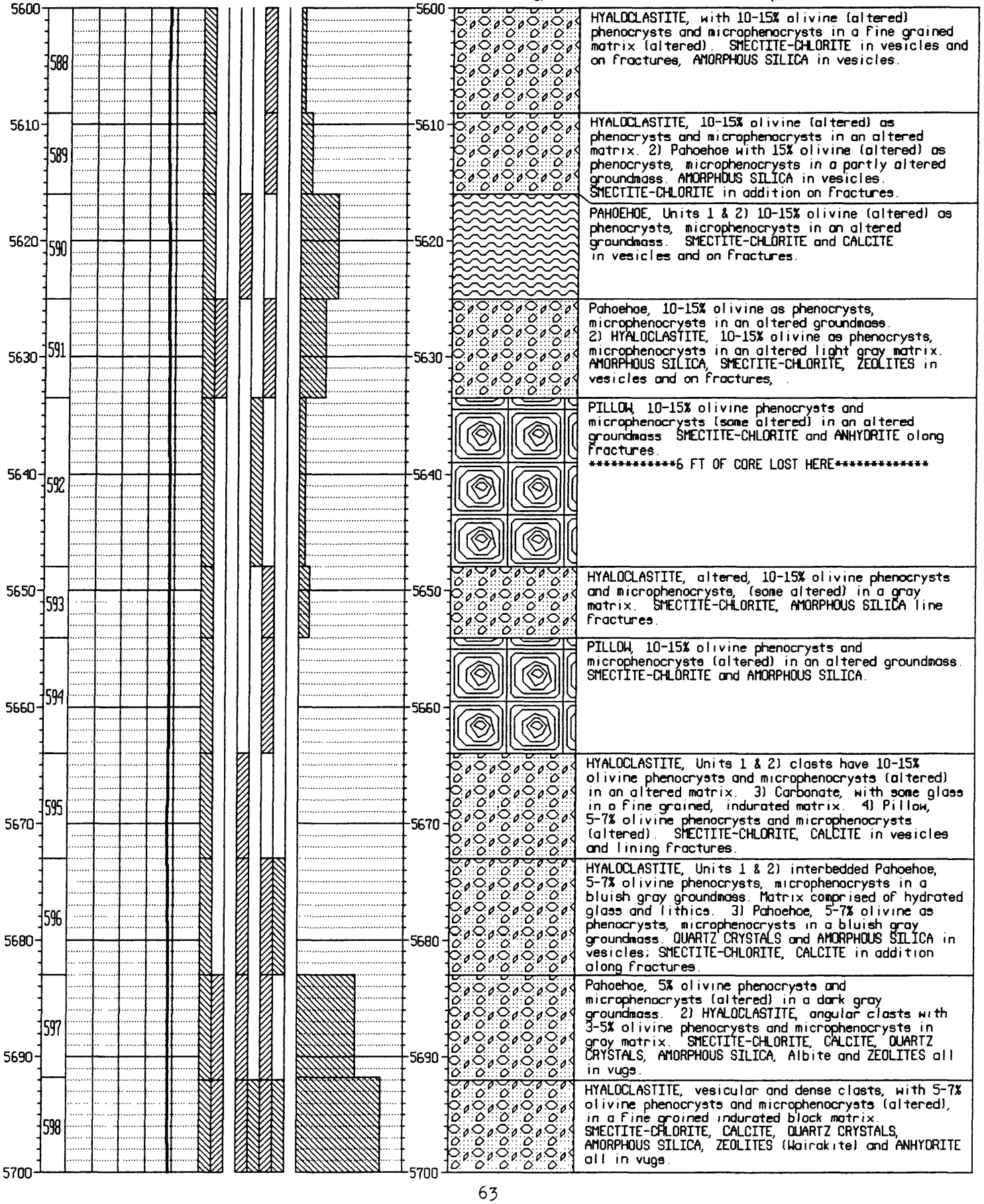

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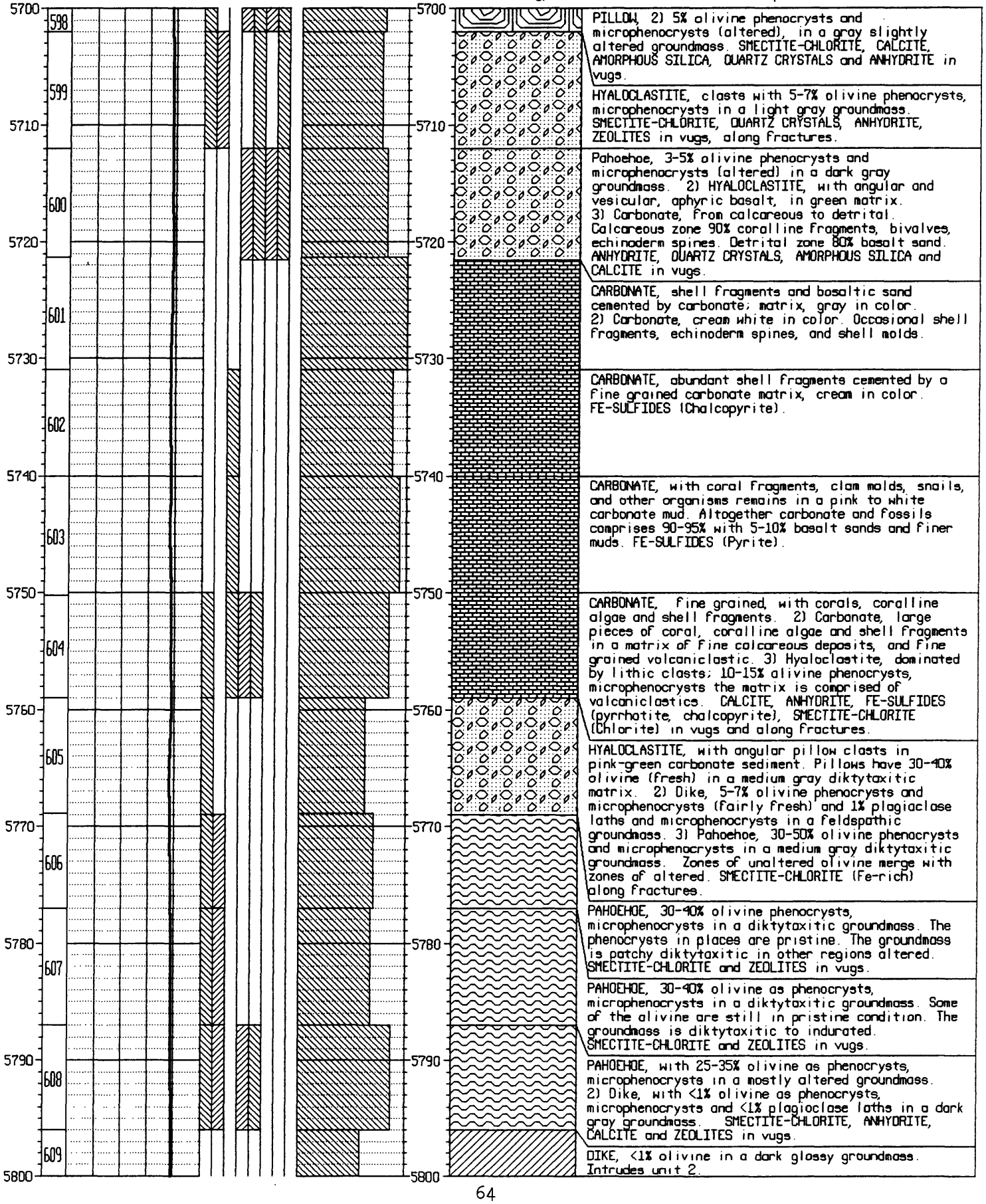

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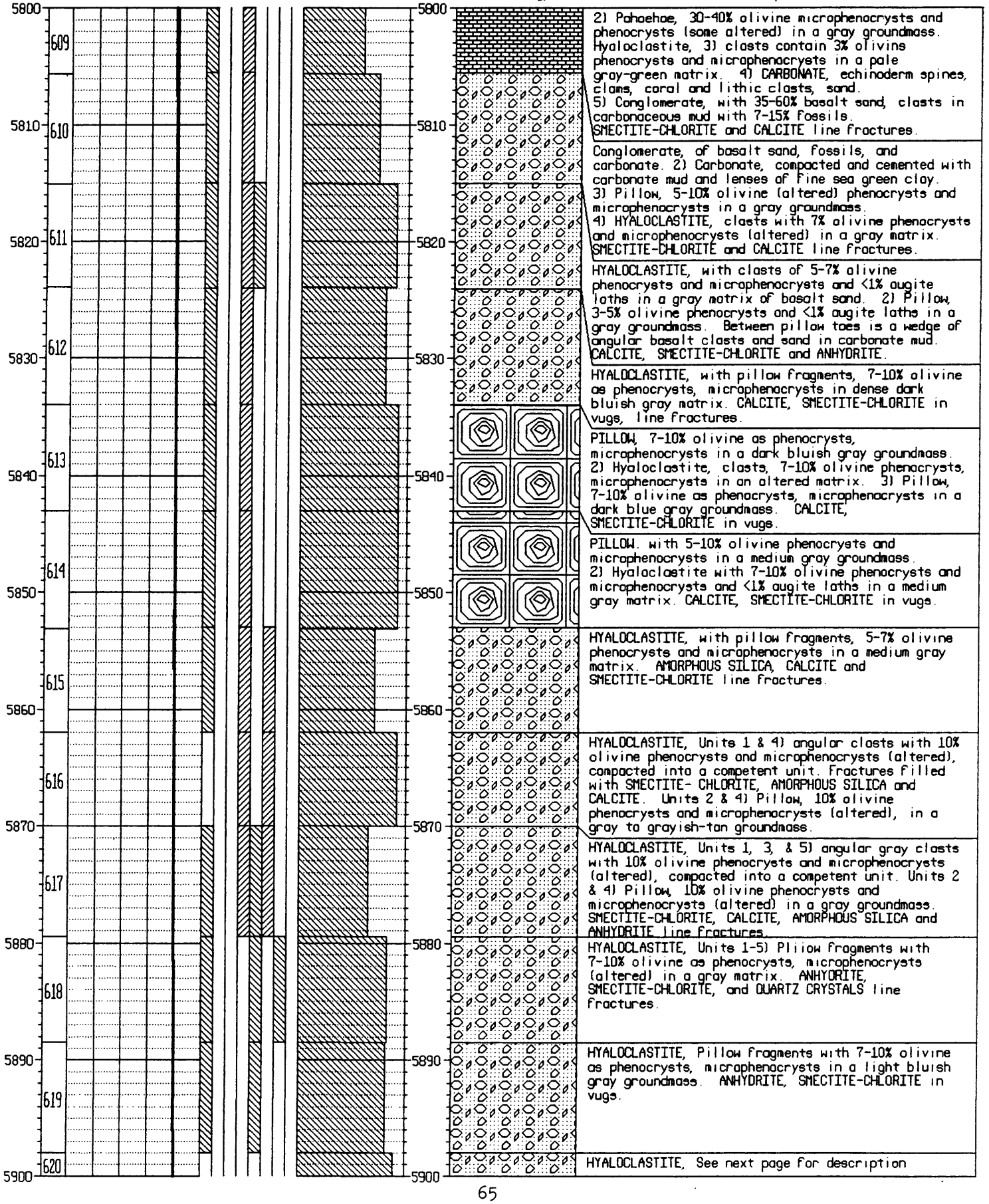

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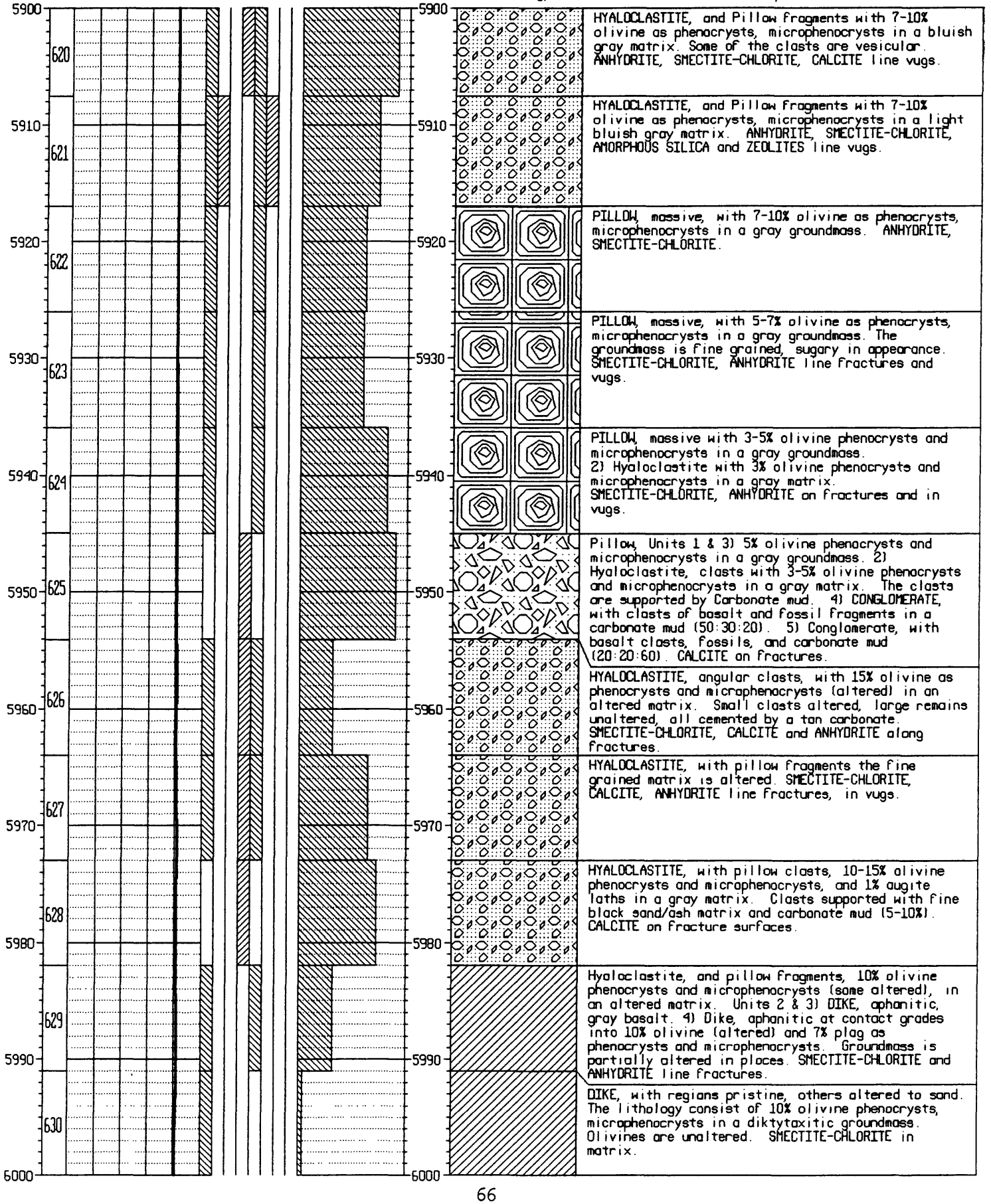
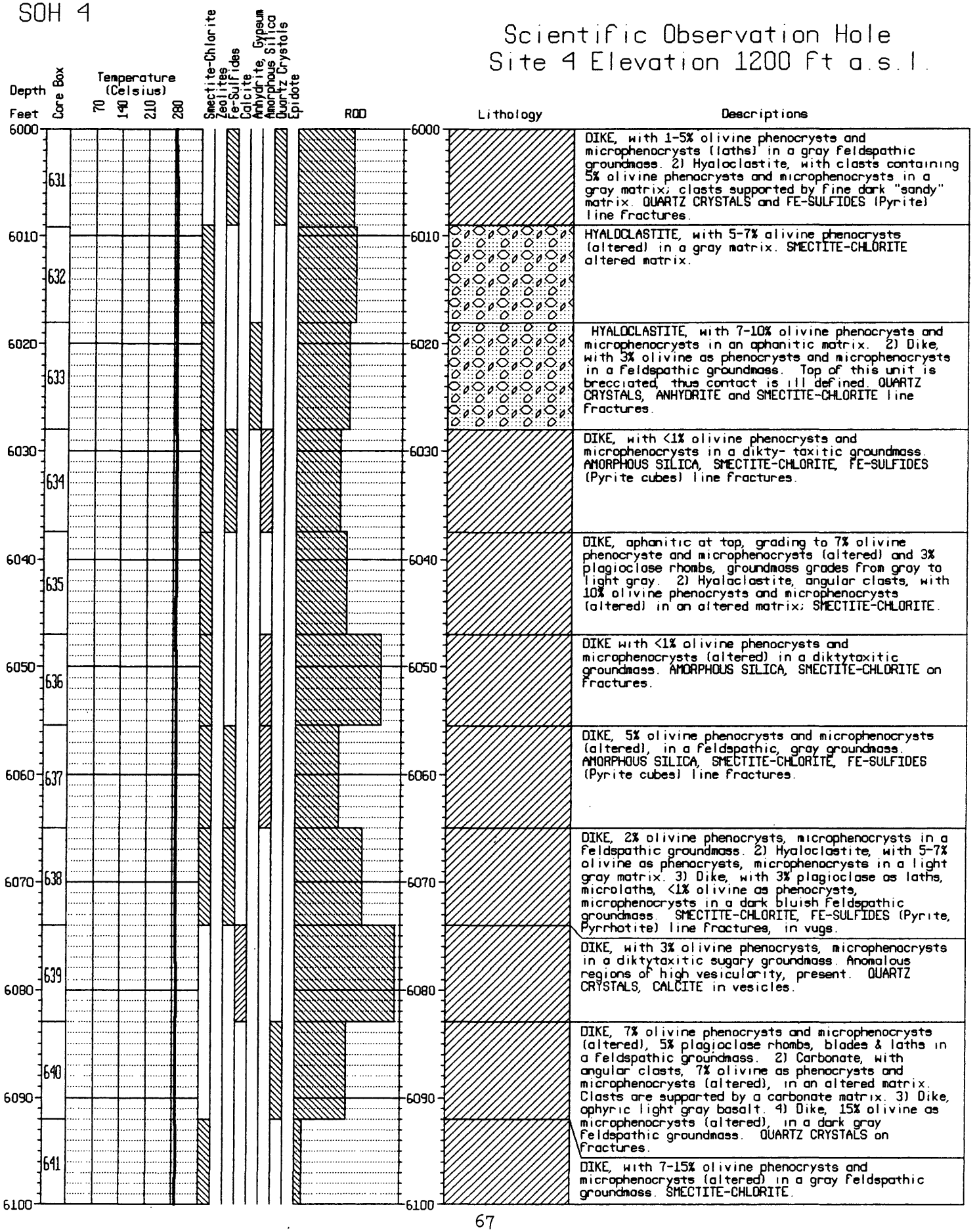


SOH 4

Scientific Observation Hole
Site 4 Elevation 1200 Ft a.s.l.



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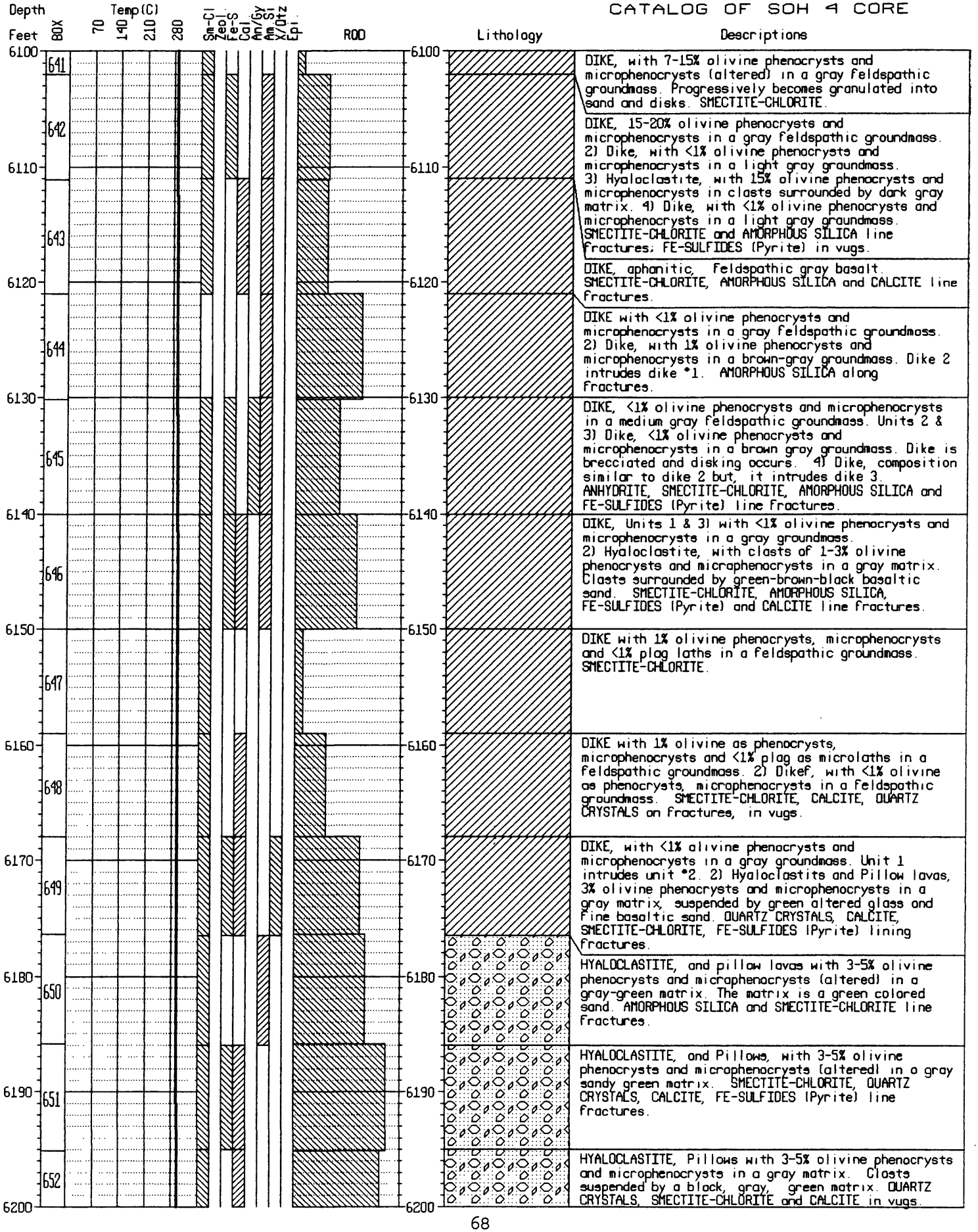

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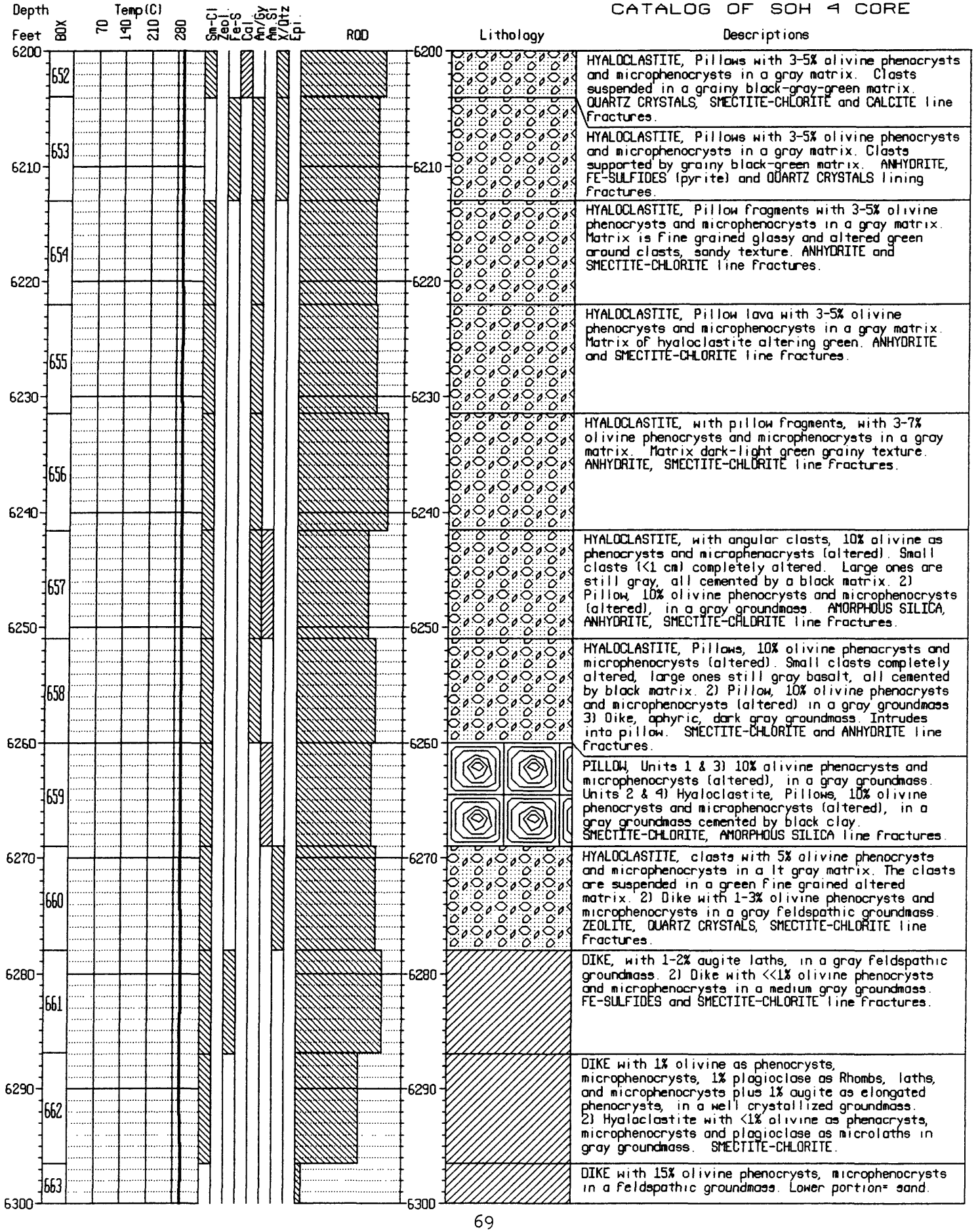

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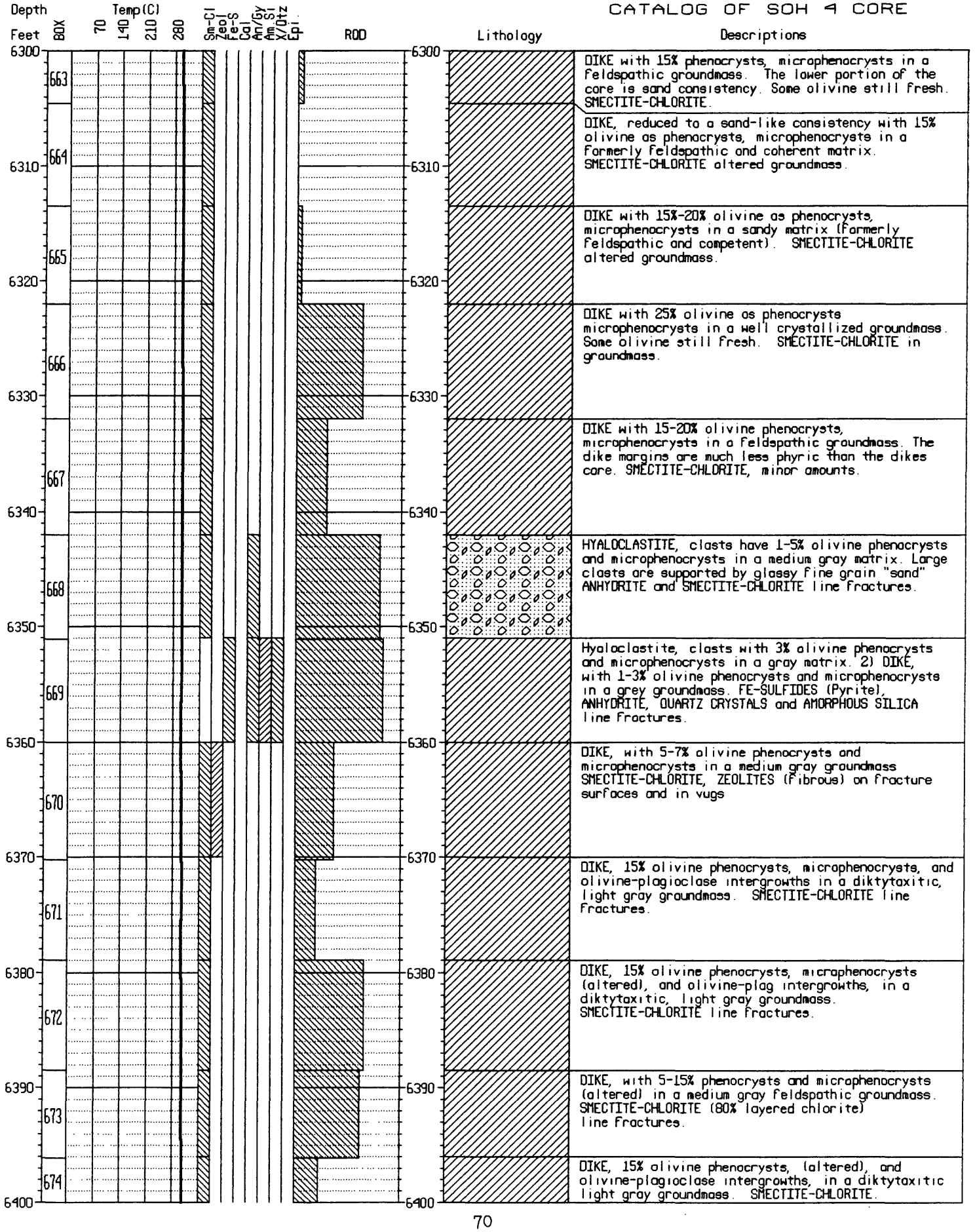

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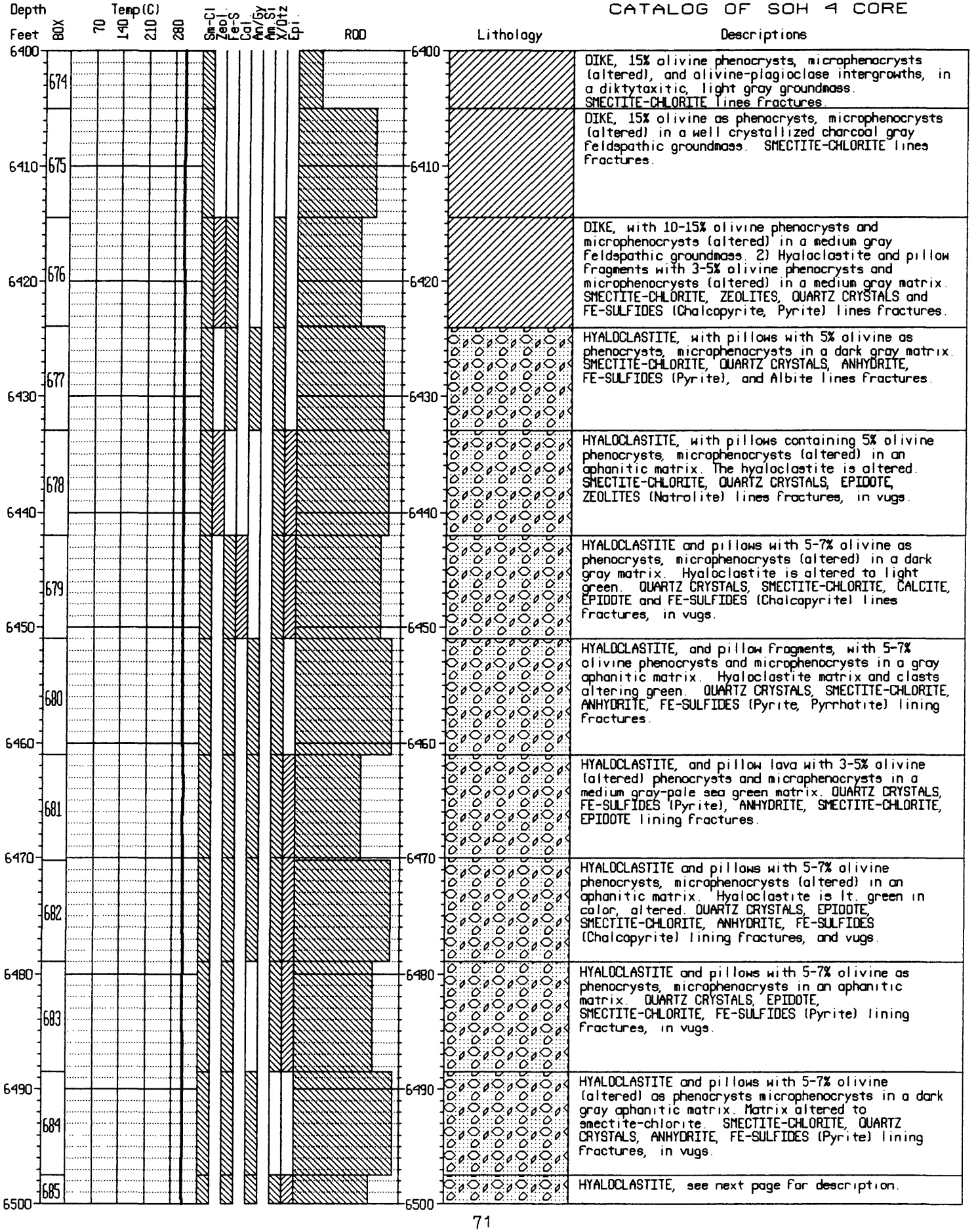

SOH 4

Scientific Observation Hole
Site 4 Elevation 1200 ft a.s.l.