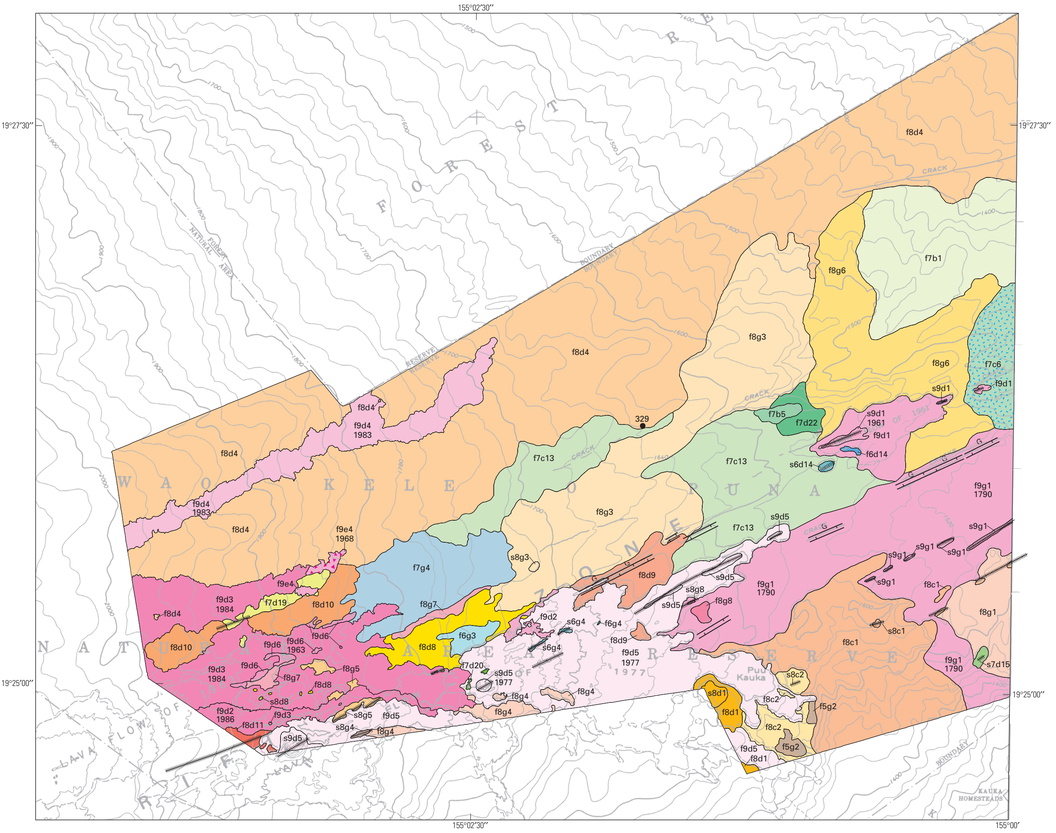


Base from U.S. Geological Survey, Kalalua, 1982
Projection and 10,000-foot grid ticks: Hawaiii coordinate system, Zone 1 (Transverse Mercator). Clarke spheroid 1866

APPROXIMATE MEAN DECLINATION, 2005

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

HAWAIIAN ISLANDS
MAP LOCATION

Geology mapped in 1990–94
Manuscript approved for publication, October 8, 1997

INTRODUCTION

Kīlauea is an active shield volcano in the southeastern part of the Island of Hawai'i (see index map). The middle east rift zone (MERZ) map includes about 27 km^2 of the MERZ and shows the distribution of the products of 37 separate eruptions during late Holocene time. Lava flows erupted during 1983–96 have reached the mapped area.

The subaerial part of the MERZ is 3–4 km wide and about 18 km long. It is a constructional ridge, 50–150 m above the adjoining terrain, marked by low spatter ramparts and cones as high as 60 m. In contrast to the northern flank of the MERZ, the southern flank is unbuttressed by Mauna Loa volcano; faulting that results from intrusion of magma into the east rift zone (Swanson and others, 1976) has resulted in a steeper topographic profile on the southern side. Normal faults having cumulative displacements of as much as 10 m have the same N. 65° E. trend as eruptive fissures and cut vent deposits and flows in and near the rift zone. Grabens often form near active vents (Richter and others, 1964, 1970). Lava typically flowed either northeast or southeast, depending on vent location relative to the topographic crest of the rift zone.

The northwestern one-third of the mapped area is underlain by extensive tube-fed pahoehoe flows erupted from the Ailaau shield on the eastern summit of Kilauea volcano (Holcomb, 1987).

The MERZ receives more than 100 in. of rainfall annually and is covered by tropical rain forest. Vegetation begins to grow on lava a few months after its eruption. Relative heights of trees can be a guide to relative ages of underlying lava flows, but proximity to faults, presence of easily weathered cinders, and human activity also affect the rate of growth.

The map is based on detailed field mapping conducted by Trusdell and Moore from 1990 to 1994. Stearns and Macdonald (1946) presented a generalized geologic map of Kilauea, showing locations of historic flows and many prehistoric vent deposits. Holcomb (1987) presented photogeologic maps of Kilauea and discussed its geologic history based mainly on paleomagnetic secular-variation studies.

The rocks have been grouped into five basic age groups. The framework for the ages assigned is provided by eight radiocarbon ages from previous mapping (Moore and Trusdell, 1991) and a single date from the current mapping effort. The numerical ages are supplemented by observations of stratigraphic relations, degree of weathering, soil development, and vegetative cover.

Rocks 1,500–3,000 years old (age group 5) cover less than 1 percent of the mapped area. Spatter and flows are deeply weathered, have 0.5–1 m of soil, and lack surficial glass. This age group is represented by a single flow.

Rocks 750–1,500 years old (age group 6) cover less than 1 percent of the mapped area. Spatter and flows are moderately weathered, have 0.2–0.5 m of soil, and have surficial glass preserved in flow creases.

Rocks 400–750 years old (age group 7) cover an estimated 15 percent of the mapped area. Spatter and flows have 0.1–0.2 m of soil, and surficial glass locally is preserved

Rocks 200–400 years old (age group 8), including summit-derived 'Ailā'au flows (Holcomb, 1987), cover 57 percent of the mapped area. Spatter and flows typically are slightly weathered and have soil less than 0.1 m thick. Surficial glass commonly is present.

One flow in the MERZ has been dated by radiocarbon at 320 ± 70 years B.P.; radiocarbon ages of several 'Ailā'au flows outside the MERZ (Holcomb, 1987) have been determined.

Rocks of historic age (age group 9) cover an estimated 28 percent of the mapped area. Eruptions occurred in 1790, 1961, 1963, 1968, 1983, 1984, and 1986. Soil cover is thin (<0.05 m) and surficial glass is common.

Small alluvial deposits are present in the MERZ but are not shown, since the underlying volcanic rocks can be recognized.

MAP UNIT SYMBOLS

Each map unit is designated by a three-, four-, or five-part symbol: (1) a letter, either s for spatter or f for flow, (2) a numeral 5–9, indicating the age group; (3) a letter, a–g, designating the petrographic type of tholeiitic basalt; and (4) a supplementary one- or two-digit numeral (sequential within each age group), if necessary, that distinguishes units in the same age group having the same petrographic symbol (for example, f9d2, f9d3, f9d5). The year of historical eruption is indicated next to the symbol.

AGE GROUPS

[After Wolfe and Morris (1996). Numbers smaller than 5 refer to age groups recognized elsewhere on the Island of Hawaii but not represented on this part of Kilauea volcano.]

9 Historical (1790 and younger)
8 200–400 years old
7 400–750 years old
6 750–1,500 years old
5 1,500–3,000 years old

PETROGRAPHIC CLASSIFICATION OF THOLEIITIC BASALT

All rocks in the mapped area are tholeiitic basalt. Rocks have been placed in one of seven categories, a through g, based on respective abundances of olivine and plagioclase phenocrysts; most rocks have less than 1 percent pyroxene phenocrysts. The assignments were made in the field and represent megascopic estimates of the volume percentages of each kind of phenocryst. In a few cases, noted in the individual descriptions of map units, abundances of olivine or plagioclase phenocrysts vary slightly from the following values.

a = picritic (> 15 percent olivine, <1 percent plagioclase)
b = 10–15 percent olivine, <1–4 percent plagioclase
c = 5–10 percent olivine, <1–4 percent plagioclase
d = <1–4 percent olivine, <1–4 percent plagioclase
e = 5–10 percent plagioclase, variable (<1–12 percent) olivine
f = >10 percent plagioclase, 1–3 percent olivine
g = aphyric (<1 percent phenocrysts)

The chemical composition of basalt in categories a, b, and c is controlled chiefly by fractionation and accumulation of olivine, and basalt of categories d, e, f, and g generally is differentiated beyond olivine control (Wright and Fiske, 1971).

Radiocarbon ages of samples from the middle east rift zone, Kilauea volcano, Hawai'i

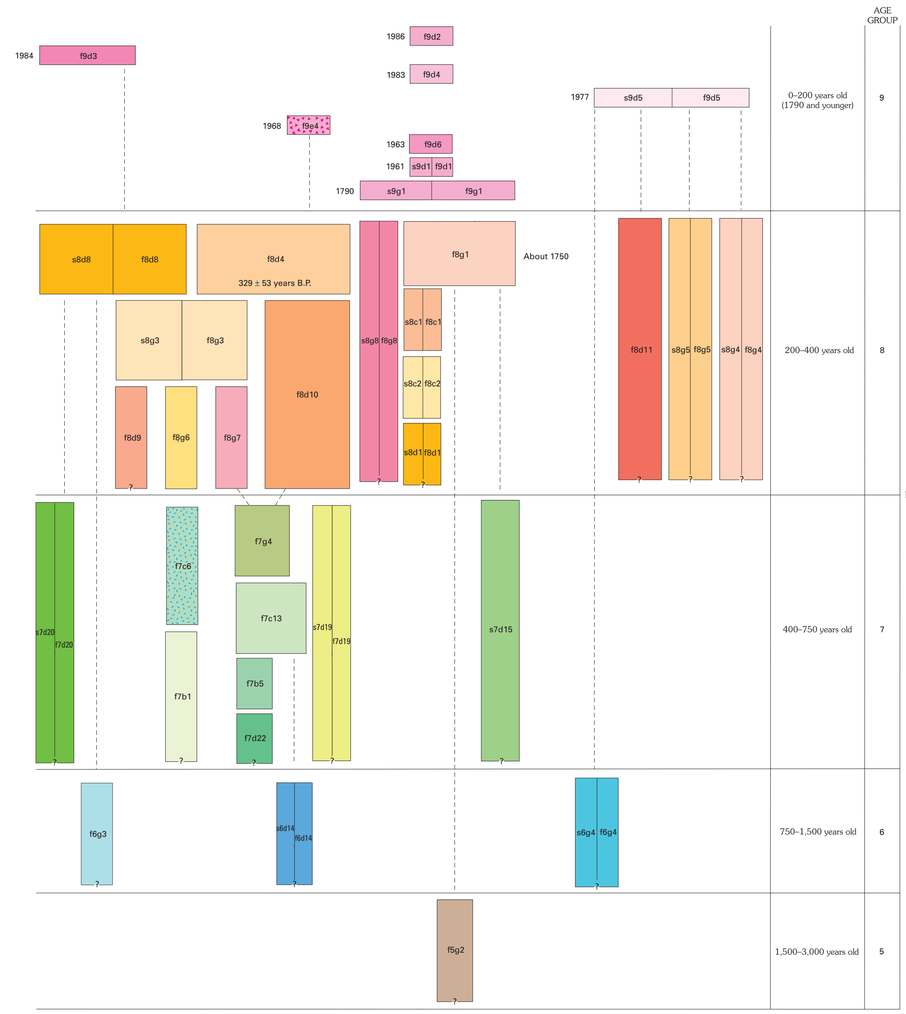
[All ages are reported in radiocarbon years before present (yr B.P., before the calendar year datum of 1950). Materials dated include charcoal, roots, twigs, vegetative litter, or unaltered wood (rarely). A variance is reported as one standard deviation in years.]

Unit label	Age group	Quality[1]	Field no.	Lab no.	Age[2] yr B.P.	S.D.[2] yr	Weighted avg. (yr B.P.)[3]	S.D.[3] yr	Age range[4]	Quadrangle 7.5 minute	Latitude (degrees[5])	Longitude (degrees[5])	Elev. (ft)	Source
f8d4	8	+	FT-92-24b	WW117	320	70	329	53	1438 to 1673	Kalalua	19.436667	-155.029333	1,411	'Ailā'au shield
f8d4	8	+	FT-92-24a	WW117	340	80	329	53	1421 to 1676	Kalalua	19.436667	-155.029333	1,411	'Ailā'au shield

[1]Quality: + = age thought meaningful; 0 = age probably meaningful but accuracy may be poorer than indicated by the reported precision. Meaningless (large analytical error) or incorrect (using all age data and regional stratigraphic relationships) ages are not reported here.
[2]Each age was calibrated to calendar years using CALIB 4.0 Radiocarbon Calibration Program (Stuiver and others, 1998); calibrated ages are for two standard deviations. Samples were processed in 1998 at the U.S. Geological Survey, Reston, VA).
[3]Multiple ages are from multiple samples; weighted avg., each age is weighted by the inverse of its variance before averaging (for example, Taylor 1982).
[4]Entire range of calendar year ages possible for a given sample.
[5]Datum, Old Hawaiian; projection, Transverse Mercator.

CORRELATION OF MAP UNITS

Undated flows are correlated to dated flows using superposition; surface exposure; color change due to solar radiation; extent of weathering; tree height, size, and girth; diversity of native plant species; and soil and ash accumulation. Units that are stacked show direct superposition relations (young over old flows). Question mark indicates that the base of the flow is concealed. Vertical dashed lines indicate units that are in contact with each other.



DESCRIPTION OF MAP UNITS

HISTORIC UNITS (1790 and younger)

f9d2 **Pāhoehoe flow of Kūpaianaha eruption of 1986**—Basalt contains 3–5 percent olivine phenocrysts and microphenocrysts and less than 1 percent plagioclase phenocrysts and microphenocrysts

f9d3 **'A'ā flow of Pu'u 'Ō'ō eruption of 1984**—Basalt contains 3–5 percent olivine phenocrysts and microphenocrysts and less than 1 percent plagioclase phenocrysts and microphenocrysts

f9d4 **A'ā flow of Pu'u 'Ō'ō eruption of 1983**—Basalt contains 3–5 percent olivine phenocrysts and microphenocrysts and less than 1 percent plagioclase phenocrysts and microphenocrysts

s9d5 f9d5 **Spatter deposits and cinder-fall deposits and extensive 'a'ā of 1977 eruption (Moore and others 1979)**—Main vent is Pu'u Kiai flow found along southern boundary of mapped area. Lava was extruded along discontinuous fissure systems eventually localizing at two central vents (Puu Kiai and vent A). Lava contains 1–3 percent plagioclase phenocrysts and microphenocrysts and less than 1 percent olivine phenocrysts and microphenocrysts

f9e4 **Pāhoehoe flow of the eruption of 1968**—Basalt contains 12 percent olivine phenocrysts and microphenocrysts and 7 percent plagioclase phenocrysts and microphenocrysts. Unit is found at the distal end of the northernmost 1984 Pu'u 'Ō'ō 'a'ā

f9d6 **Extensive 'a'ā of 1963 eruption (Moore and Koyanagi, 1969)**—Lava was extruded along discontinuous fissure systems eventually. Basalt contains 1–5 percent olivine phenocrysts and microphenocrysts. Unit is partially buried by the southernmost 1984 Pu'u 'Ō'ō 'a'ā

s9d1 f9d1 **Spatter deposits and extensive pāhoehoe of 1961 eruption (Richter and others, 1964)**—Main vent and flow found near the eastern boundary of mapped area. Basalt contains 0–5 percent olivine phenocrysts and microphenocrysts

s9g1 f9g1 **Spatter deposits and extensive pāhoehoe erupted about 1790**—Lava was extruded along discontinuous fissure systems in the east-central part of the mapped area. Lava contains less than 1 percent olivine phenocrysts and microphenocrysts

UNITS 200–400 YEARS OLD

f8d4 **Extensive pāhoehoe flows**—In the northern part of the map, flows underlie about 30 percent of mapped area. Source is the 'Ailā'au shield (Holcomb, 1987) at the eastern side of summit caldera of Kilauea. Basalt contains variable amounts of olivine and plagioclase. Flow contains 1–7 percent olivine phenocrysts and microphenocrysts and 0–3 percent plagioclase phenocrysts and microphenocrysts. Average age 329 ± 53 radiocarbon yr B.P.

s8c1 f8c1 **Spatter deposits and limited pāhoehoe flows in the eastern part of the mapped area**—Unit underlies Heiheiahulu pāhoehoe (f8g1) with no intervening soil. Deposits formed early stages of eruption that became centralized at Heiheiahulu. Basalt contains 4–8 percent olivine and 3–5 percent plagioclase phenocrysts

s8c2 f8c2 **Spatter deposits, cinder-fall deposits, and pāhoehoe flows of Kaimū-Makena Homestead**—Flows extruded from cinder cone in southeastern part of mapped area. Basalt contains 3–7 percent olivine phenocrysts and less than 2–3 percent plagioclase phenocrysts

s8d1 f8d1 **Spatter deposits, cinder-fall deposits, and 'a'ā flow of Kalapana**—Unit found in southeastern part of mapped area. Basalt contains 3–5 percent plagioclase phenocrysts

f8g1 **Heiheiahulu spatter and flows at the southeastern boundary of the mapped area**—Flows originate from a large shield complex just east of the mapped area. Basalt contains no phenocrysts of olivine or plagioclase. Oral Hawaiian legends suggest that Heiheiahulu erupted about 1750 (Stearns and Macdonald, 1946)

s8g3 f8g3 **Spatter deposits and extensive pāhoehoe and limited 'a'ā flows in central parts of mapped area**—Basalt contains less than 1 percent olivine and less than 1 percent plagioclase laths. This unit is overlain by Pu'u Kiai 'a'ā (f9d4)

s8g4 f8g4 **Pahoehoe flows at south-southwestern boundary of mapped area**—Lava extruded from spatter ramparts partially buried by 1977 flows. Basalt contains less than 1 percent olivine microphenocrysts and less than 1 percent plagioclase laths

s8g5 f8g5 **Spatter deposits and limited pāhoehoe flows partially buried by 1984 Pu'u 'Ō'ō 'a'ā, Kūpaianaha pāhoehoe, and 1977 flows**—Basalt contains 0–1 percent olivine microphenocrysts and less than 1 percent plagioclase laths. Microgabbroic xenoliths less than 1 cm in diameter occasionally found in hand sample

f8g6 **Extensive pāhoehoe flows at northeastern margin of mapped area, north and east of 1961 flow**—Basalt is aphyric

f8g7 **Pāhoehoe flow extruded from a ground crack in west-central part of mapped area**—Areal distribution very limited in extent; unit found as two separate flow fields. Uprift segment is a pāhoehoe at eastern edge of the 1984 Pu'u 'Ō'ō-'a'ā flows. The other segment is found between flow units f8d8 and f7g4 in the center of the mapped area. Basalt contains 0–1 percent olivine microphenocrysts and less than1 percent plagioclase laths

s8g8 f8g8 **Spatter deposits and 'a'ā in south-central part of mapped area**—Areal distribution very limited in extent. The unit is found as kīpuka in 1790 (f9g1) deposits. Basalt contains 0–1 percent each of olivine and plagioclase phenocrysts

s8d8 f8d8 **Spatter deposits and pāhoehoe flows extruded from spatter cone almost completely buried by 1984 Pu'u 'Ō'ō-a'ā**—Basalt contains 1–2 percent plagioclase laths and rare olivine phenocrysts and microphenocrysts, all in a gray feldspathic groundmass

f8d9 **Pāhoehoe flow at center of the mapped area, near distal end of 1977 flow**—Basalt contains 1 percent olivine phenocrysts

f8d10 **Pāhoehoe flow near the western boundary of the mapped area between the 1983 and 1984 Pu'u 'Ō'ō-'a'ā flows**—Basalt contains 1–2 percent plagioclase phenocrysts

f8d11 **Pāhoehoe flow at western boundary of the mapped area between the 1986 Kūpaianaha pāhoehoe and 1977 Pu'u Kiai 'a'ā flows**—Basalt contains 1–2 percent plagioclase phenocrysts

UNITS 400–750 YEARS OLD

f7g4 **Pāhoehoe flow in central part of mapped area at distal end of 1984 Pu'u 'Ō'ō 'a'ā**—Basalt contains less than 1 percent olivine phenocrysts and 0–1 percent plagioclase phenocrysts

s7d19 f7d19 **Spatter deposits, cinder-fall deposits, and pāhoehoe flows extruded from cinder cone near western boundary of the mapped area between two lobes of 1984 Pu'u 'Ō'ō 'a'ā**—Basalt with 1–2 percent olivine phenocrysts and microphenocrysts and 2–3 percent plagioclase phenocrysts in a feldspathic, gray groundmass

s7d20 f7d20 **Spatter deposits and pāhoehoe flow near boundary of the 1984 Pu'u 'Ō'ō 'a'ā and 1977 flow field**—Basalt contains 1–3 percent plagioclase phenocrysts and less than 1 percent olivine phenocrysts and microphenocrysts

f7b1 **Extensive 'a'ā and pāhoehoe flow**—At northeastern part of mapped area. Basalt contains 10–20 percent olivine and less than 1 percent plagioclase phenocrysts

f7c6 **Pāhoehoe flow**—At eastern edge of mapped area. Basalt contains 3–6 percent olivine phenocrysts

s7d15 **Spatter deposits surrounded by Heiheiahulu flows at the southeastern boundary of the mapped area**—Basalt contains 3–5 percent olivine phenocrysts and 1–2 percent plagioclase phenocrysts and microphenocrysts

f7b5 **Pāhoehoe flow in east-central part of the mapped area**—Basalt contains 10–15 percent olivine phenocrysts and microphenocrysts and less than 1 percent plagioclase phenocrysts

f7d22 **Pāhoehoe flow in east-central part of the mapped area**—Basalt contains 1–2 percent olivine phenocrysts and microphenocrysts and less than 1 percent plagioclase phenocrysts

f7c13 **Extensive pāhoehoe flow in central part of the mapped area**—Basalt contains 3–7 percent olivine phenocrysts and microphenocrysts and less than 1 percent plagioclase phenocrysts

UNITS 750–1500 YEARS OLD

f6g3 **Minor spatter deposits, cinder-fall deposits, and pāhoehoe flows extruded from cinder cone in southwestern part of mapped area at the north edge of the 1977 Pu'u Kiai flow field**—Basalt contains less than 1 percent plagioclase laths

s6d14 f6d14 **Spatter deposits, cinder-fall deposits, and pāhoehoe flows extruded from cinder cone southwest of 1961 flow**—Basalt contains 2–4 percent olivine phenocrysts and less than 1 percent plagioclase laths

s6g4 f6g4 **Spatter deposits, cinder-fall deposits, and 'a'ā flows extruded from spatter ramparts in south-central part of mapped area**—Unit is a kīpuka within the larger 1977 flow field. Basalt contains less than 1 percent each of olivine and plagioclase phenocrysts

UNITS 1500–3000 YEARS OLD

f5g2 **'A'ā and pāhoehoe flows in southeastern part of mapped area south of the easternmost 1977 Pu'u Kiai flow field**—Basalt contains less than 1 percent plagioclase and olivine phenocrysts

Graben

Ground crack

Fissure vent

329 **Sample locality for radiocarbon-dated sample**

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Meyer Rubin (U.S. Geological Survey) determined radiocarbon ages. Lisa Morgan and Edward Wolfe reviewed the map.

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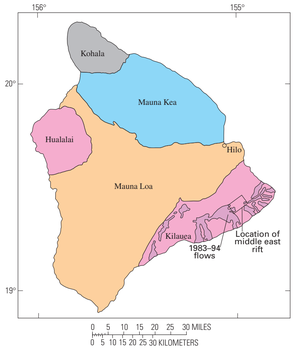

INDEX MAP OF THE ISLAND OF HAWAI'I SHOWING ITS FIVE VOLCANOES (AFTER PETERSON AND MOORE, 1987). STIPPLED AREAS SHOW APPROXIMATE LOCATIONS OF HISTORIC ERUPTIONS OF KĪLAUEA, INCLUDING THE CONTINUING 1983–90 ACTIVITY. AREA OF MAP IS OUTLINED

GEOLOGIC MAP OF THE MIDDLE EAST RIFT GEOTHERMAL SUBZONE, KĪLAUEA VOLCANO, HAWAI'I

By
Frank A. Trusdell and Richard B. Moore

2006

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