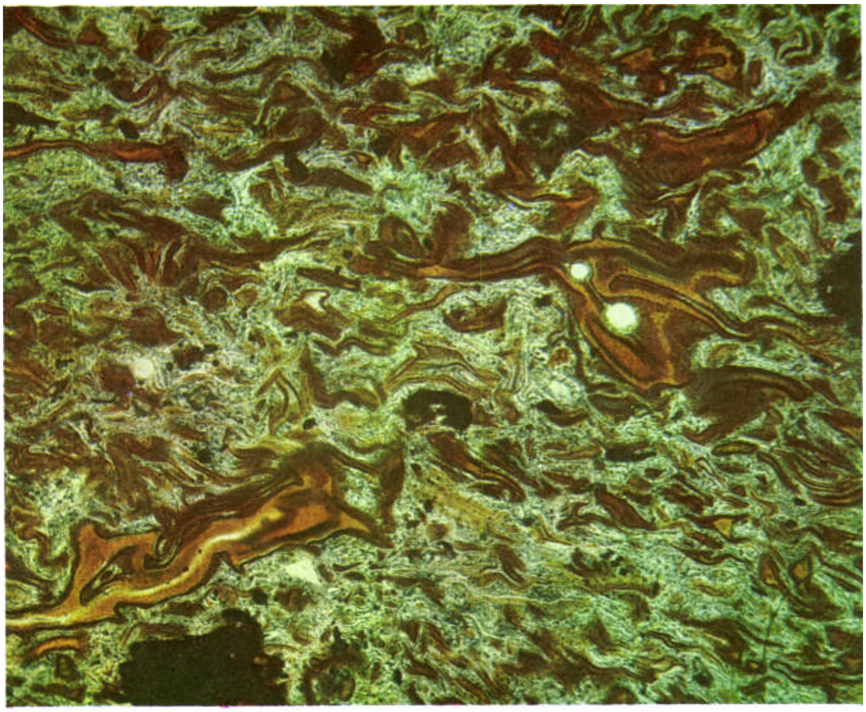
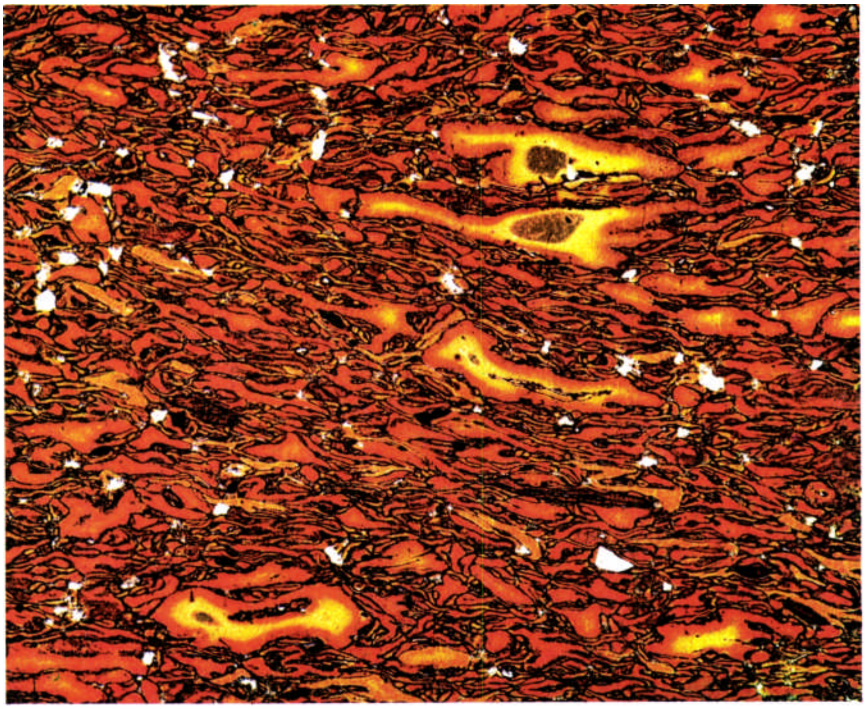


Thin section showing oxidation and later partial reduction of the iron in a glassy welded tuff. Iddings (1899, pl. 50, fig. B) shows the same section in black and white. His belief that this was all originally red and that bleaching took place after deposition is confirmed by the presence of very fine grained microlites of magnetite in the light-colored area. From Yellowstone National Park.



The dull brown cores of the large shards near the middle of this photomicrograph of glassy welded tuff represent the original character of the glass, and the red areas are a result of oxidation. The horizontal alinement of shards indicates marked compaction. USNM specimen 38771 from Rio Blanco, 10 miles north-northwest of Guadalajara, Mexico.

OXIDATION AND REDUCTION IN GLASSY WELDED TUFFS

Ash-Flow Tuffs: Their Origin, Geologic Relations and Identification

and

Zones and Zonal Variations in Welded Ash Flows

with Foreword by
ROBERT L. SMITH

Reprinted from U.S. Geological Survey
Professional Papers 354-F and 366

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FOREWORD

by

Robert **L. Smith**

Twenty years have passed since publication of U.S. Geological Survey Professional Papers 366, *Ash-flow tuffs: Their origin, geologic relations and identification,* by C. S. Ross and R. L. Smith (1961), and 354-F, *Zones and zonal variations in ash-flows,* by R. L. Smith (1960). As these papers are now being republished, perhaps a few words are appropriate to clarify their historical evolution and to view them in the context of the present time.

Clarence Ross and I began an intensive general study of microscopic and field characteristics of "welded tuffs" in 1948, in the hope that such a study would aid our interpretation of the Bandelier Tuff, Jemez Mountains, New Mexico. The study led to a general overview which became Professional Paper 366. Professional Paper 366 was written during the late 1940's and early 1950's. The paper was virtually complete in its present form in 1954 and should have been published in 1955 or 1956. For various reasons the paper with but minor updates to about 1956, did not go to press until 1960, and we feared that it would be obsolete before it was published. Moreover, the first printing of PP366 in 1960 was contracted out by the Government Printing Office and the reproduction of the plates was unacceptable and reprinting was required. This reprinting by GPO delayed the publication date until 1961 *after* the publication of PP 354-F and my review paper "Ash Flows" (1960). For the specialist in welded tuffs Professional Paper 366 probably was obsolete when published, but fortunately specialists were few and the paper has long been popular and useful to students, teachers and to geologists not specialized in the geology of silicic volcanic rocks. Professional Paper 354-F was conceived during the mid-1950's, written in 1958, and published in June of 1960, the same month that "Ash Flows" appeared in the Geological Society of America Bulletin. This latter paper was written in 1959 and, although it was labeled a review paper, it actually represented a five-year conceptual advance beyond Professional Paper 366, and contained much additional data. However, the main value of Professional Paper 366 is in the many photomicrographs depicting variations in ash-flow tuffs, and in the historical summary that attempts to outline the evolution of thought leading to modern concepts. These sections are probably of most value to students and have not yet been superseded.

Professional Paper 354-F introduces the concept of the "cooling unit" and provides some genetic and descriptive order to the many lithological variations found in welded tuffs. The cooling unit was conceived by the author as a device to provide genetic meaning to map units, as well as an aid to mapping, and had its origin in the very complex units of the Bandelier Tuff. The fact that no Bandelier-type units are depicted in Professional Paper 354-F, has puzzled several observant students of these rocks, and on several occasions I have been asked "why?"

Professional Paper 354-F deals primarily with zonal variations in what I termed "simple cooling units" and although concepts of more complex units were introduced they were not illustrated. The more complex units were to have been the subjects of a sequel to the paper. Illustrations, an oral presentation and an abstract were prepared for an International Association of Volcanology and Chemistry of the Earth's Interior symposium in 1962 in Italy, but alas! the paper was never written.

The cooling-unit concept was built around the premise that the two major variables controlling the lithologic variations in welded tuffs are emplacement temperature of the ash flows and the thickness of the resulting deposit. As originally planned, Professional Paper 354-F was to have been written around a thickness-temperature hierarchy of examples of actual cooling units, but this proved to be impractical at the time. Instead, the model was developed from the then existing fragments of cooling units whose properties could be reasonably extrapolated from one deposit to another.

The sources for the illustrations in plate 20 of the original PP354-F may now be of historical interest. Figure A was patterned after the Battleship Rock Tuff, Jemez Mountains, New Mexico; figure B was patterned after the Walcott Tuff of Idaho; figures C and D are hypothetical composites based on observations of a large number of vertical sections of devitrified units seen over a period of years in the western United States. A detailed listing of these units, even if they could all be recalled, is impractical here, but the welded tuffs of the San Juan Mountains, Yellowstone, and southeastern Utah, certainly played a dominant role.

Once these "simple" patterns of plate 20 were rationalized in a temperature-thickness context, the "compound" nature of the Bandelier Tuff units could then be recognized and understood in terms of a cumulative series of ash flows of systematically increasing emplacement temperatures and, ultimately, of changing compositions. Much of this reminiscence now seems trivial but in the 1940's and 1950's there were major problems. For years we were puzzled as to why "vitrophyre zones," so common under many welded tuff sheets, are absent in the Bandelier Tuff outside the caldera, but present inside. This can now be explained by the compound nature of the Bandelier cooling units. Such an explanation gives insight into eruption mechanics.

The "zone of granophyric crystallization" was postulated on the basis of observations made on a very thick cooling unit in the Chiricahua Mountains, Arizona (Member 6 of Enlows, 1955) and on the Superior Dacite (now Apache Leap Tuff of Peterson, 1969), Arizona. The "zone of fumarolic alteration" was largely speculative and, although eroded off in most tuffs, probably exists only as a discontinuous zone in most tuff sheets. In 1975 I encountered for the first time a continuous "zone of fumarolic alteration" on the ash flows surrounding Okmok caldera on Umnak Island, Aleutian Islands, Alaska. This zone was nearly everywhere present and ranged in thickness from about 0.1 to about 3 meters.

Professional Papers 366 and 354-F should be updated, amplified and recast into a simple quantitative synthesis of those rocks that we know as ash-flow tuffs. I have toyed with the idea for some years, butto date have only outlined the problem. The completion of such a complex task would be professionally rewarding and of interest to advanced students, but would destroy the simplicity that makes these publications useful to beginning students.

Modern studies of ash-flow tuffs are becoming strongly focused in two directions: 1) Mathematical modeling of eruption mechanics and 2) quantitative evaluation of chemical and mineralogical evolution. Of the two main areas of study, I think that eruption mechanics is fascinating and particularly significant if extended to problems of magma generation, magma rise in the crust, and plate tectonics. However, I also think that studies that relate to the chemical evolution of magmas, volcano periodicity and prediction, crustal evolution, ore deposits and their reserves, and certain energy resources will form a major wave of future research in earth science. Riding the crest of the wave will be in-depth studies of pyroclastic rocks, particularly ash-flow tuffs. We have only just begun to tap the real wealth of knowledge stored in these rocks.

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PREFACE

Both of these papers have been out-of-print for a number of years, much to the dismay of an ever-growing number of geologists who by choice or necessity find themselves working with volcanic rocks. Because much of the pioneering work on ash-flow tuffs described in both papers was done in New Mexico and because New Mexico, as well as the rest of the southwestern United States and northern Mexico, contains widespread accumulations of ash-flow tuffs that are currently under intensive study, the New Mexico Geological Society felt it was both appropriate and timely to re-issue these two classic contributions to modern volcanology. The actual reprinting effort would not have been realized, however, without the enthusiastic support and full cooperation of the U.S. Geological Survey's Office of Scientific Publications which supplied all of the original photographic plates.

Just to keep the record straight, the original inspiration to reprint the two papers also stems, in no small part, from a long, frustrating and ultimately unsuccessful search for an original copy of Professional Paper 366 for my own library.

James M. Robertson, Past President,
New Mexico Geological Society

Ash-Flow Tuffs: Their Origin Geologic Relations and Identification

By CLARENCE S. ROSS *and* ROBERT L. SMITH

GEOLOGICAL SURVEY PROFESSIONAL PAPER 366

A study of the emplacement, by flowage, of hot gas-emitting volcanic ash; its induration by welding and crystallization, and criteria tor recognizing the resulting rock

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1961

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

First printing 1961
Second printing 1964
Third printing 1968

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