



FRONTISPIECE.—The two major remaining pieces of the Port Orford, Oregon, meteorite specimen. The Vienna specimen (#A662, 3.47 g) is at the left of the specimen at the National Museum of Natural History, Washington, D.C. (USNM#617, 17.7 g, 28 mm high). Blue-black fusion crust covers much of the Vienna specimen and is present in small patches particularly at the top of the larger specimen. Light yellow olivine may be seen in both specimens. Photograph by Chip Clark, Smithsonian Institution.

The Port Orford, Oregon, Meteorite Mystery

Roy S. Clarke, Jr.

EDITOR

ISSUED

JAN 04 1993

SMITHSONIAN INSTITUTION



SMITHSONIAN INSTITUTION PRESS

Washington, D.C.

1993

ABSTRACT

Clarke, Roy S., Jr., editor. The Port Orford, Oregon, Meteorite Mystery. *Smithsonian Contributions to the Earth Sciences*, number 31, 43 pages, Frontispiece, 19 figures, 7 tables, 1993.—The Port Orford meteorite was allegedly discovered by John Evans, a contract explorer for the United States Government, on a mountain in southwestern Oregon in 1856. Efforts to organize the recovery of the alleged 10-ton body for placement in the Smithsonian Institution in Washington, D.C., began in late 1859, but were abandoned as a consequence of the simultaneous onset of the Civil War and Evans' death.

Early in this century journalistic reports revived the story and stimulated numerous unsuccessful amateur meteorite hunting expeditions into the inaccessible Siskiyou National Forest. Smithsonian investigators visited the vaguely defined site without success in 1929 and 1939. As time passed, it became increasingly obvious to some involved officials that there was something wrong with the original accounts. Nevertheless, most persons persisted in their belief that Evans' story was true.

This monograph combines an historical study by Howard Plotkin ("John Evans and the Port Orford Meteorite Hoax," pages 1-24), and a technical study by V.F. Buchwald and Roy S. Clarke, Jr. ("A Mystery Solved: The Port Orford Meteorite is an Imilac Specimen," pages 25-43).

In the first paper, Plotkin details the history of the mysterious lost Port Orford meteorite, and presents previously unreported evidence that indicates Evans was ill-trained for his scientific field work, which was superficially and unprofessionally executed, and that he had amassed a staggering personal debt by consistently overspending his budget. Most startling of all, Plotkin's research led him to the inescapable conclusion that Evans had acquired a small but very rare piece of meteorite, and had hatched a clever scheme whereby he could use it to turn around his financial affairs. Plotkin reconstructs in detail how Evans planned to carry out this hoax.

Finally, Plotkin endeavors to establish the true identity of the meteoritic sample. On the basis of its overall physical appearance, degree of weathering, and chemical composition, Plotkin argues that the Port Orford specimen is a fragment of Imilac, a Chilean pallasite discovered in 1820-1822. He further contends that Evans acquired it from someone else while crossing the Isthmus of Panama on his final return trip from Oregon during the fall of 1858.

In the second paper, Buchwald and Clarke describe the involvement of the National Museum of Natural History in attempts during this century to recover the meteorite, and they report on their detailed technical studies of the Port Orford specimen and other possibly related meteorites.

Buchwald and Clarke point out that only three distinct pallasite falls were known in the late 1850s: (1) the single Krasnojarsk, Siberia, mass, (2) the two large masses of the Brahmin, Belorussiya, meteorite, and (3) the Imilac, Chile, shower. Both Krasnojarsk and Brahmin were ruled out of a possible hoax scenario on the basis of physical properties and state of corrosion, which left Imilac as the only possibility short of invoking an otherwise completely unknown fall. They therefore undertook detailed metallographic and mineralogical examinations of the Port Orford specimen and several Imilac specimens in an attempt to resolve the matter.

They find that the Port Orford specimen is a main group pallasite that is chemically, structurally, and morphologically indistinguishable from Imilac. The steep thermal gradient of its heat-altered zone shows it to be an individual from a shower-producing fall and that it could not have been a specimen removed from a large mass. Its weathering history suggests the arid conditions of the high desert of Chile, not the humid Oregon coast forests. Port Orford's kamacite composition and hardness, olivine composition, trace element levels in metal, and shock levels in kamacite and troilite are all within observed ranges for the Imilac shower or within reasonable extensions thereof. These many congruencies led Buchwald and Clarke to conclude that the Port Orford meteorite is an Imilac specimen, and that Evans perpetrated a deliberate hoax using a small Imilac individual as bait.

OFFICIAL PUBLICATION DATE is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, *Smithsonian Year*. SERIES COVER DESIGN: Volcanic eruption at the island of Krakatau in 1883.

Library of Congress Cataloging-in-Publication Data
The Port Orford, Oregon, meteorite mystery / Roy S. Clarke, Jr., editor.
p. cm.—(Smithsonian contributions to the earth sciences ; no. 31)
Includes bibliographical references.
I. Port Orford meteorite—History. I. Clarke, Roy S. II. Series.
QB756.P67P67 1992 523.5'1'0979521—dc20 92-26788

∞ The paper used in this publication meets the minimum requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48—1984.

Contents

	<i>Page</i>
EDITOR'S PREFACE	vi
1. JOHN EVANS AND THE PORT ORFORD METEORITE HOAX, by Howard Plotkin	1
Introduction	1
Acknowledgments	7
Rationale for a New Field Search	7
Identification of Bald Mountain	8
Author's Field Searches	9
Evans' Stature as a Scientist	11
Motivation for the Hoax	13
Reconstruction of the Hoax	15
Identity of the Port Orford Specimen	18
Conclusion	21
Notes	22
2. A MYSTERY SOLVED: THE PORT ORFORD METEORITE IS AN IMILAC SPECIMEN, by Vagn F. Buchwald and Roy S. Clarke, Jr.	25
Introduction	25
Acknowledgments	27
Pallasites and Their Early History	27
Examination of Specimens	29
Port Orford Specimen USNM#617	30
The Vienna Port Orford Specimen #A662	34
The Arizona State University, Port Orford Specimen #1100	34
The Natural History Museum, London, Port Orford Specimen #1985,M.187	35
The Geological Survey of India, Calcutta, Port Orford Specimen #I 1	36
Imilac Specimens	36
Discussion	36
Characteristics Derived from the Parent Body	36
Properties Related to Atmospheric Passage	37
Weathering History	40
Other Possible Pairings	40
Conclusions	41
Notes	41
Literature Cited	42

Editor's Preface

This combined presentation of an historical and a technical study of the enigmatic Port Orford, Oregon, meteorite in *Smithsonian Contributions to the Earth Sciences*, although unusual, is appropriate. The Smithsonian Institution was drawn into explorer John Evans' Port Orford meteorite affair as the story began to unfold in about 1860, an early date in Smithsonian history. For most of this century Smithsonian officials have been plagued by the ensuing myth created by irresponsible reporting, as have officials of other agencies both in Washington, D.C., and in Oregon. In addition, hundreds of adventurers and treasure hunters have been misled, and a few endangered.

Howard Plotkin, an historian of science, was drawn to the mountains overlooking Oregon's Pacific Ocean coast by the Port Orford myth in 1986 and again in 1987. He hoped that this field work might yield information leading to the recovery of the legendary 10-ton meteorite that had been reported some 130 years earlier but has never been relocated. In his paper he recounts how this field work, in conjunction with his manuscript research, led to a reinterpretation of the character and career of John Evans. A completely new approach to the Port Orford mystery resulted. The main conclusion Plotkin draws is that the Port Orford meteorite specimen was a prop in a deliberate and elaborate hoax. The specimen, he further concludes, was actually from the well-known Imilac, Chile, meteorite shower.

As Curator-in-Charge of the collection that now houses the Port Orford specimen, I had provided Plotkin with information on the Port Orford mystery. As a consequence, he sent me an early draft of his manuscript in the late summer of 1987, shortly before Vagn Buchwald arrived in Washington, D.C., from Copenhagen for a sabbatical visit. We were both fascinated with the new insight provided by Plotkin's work, and it proved a timely juxtaposition of backgrounds and interests.

Experience gained in working with the meteorite collection and in answering the many Port Orford meteorite queries had led me to conclude by the mid 1970s that the Port Orford specimen was actually a piece of the Imilac shower, but I could not prove it. Buchwald previously had done extensive field and laboratory work on the Imilac shower and, with my encouragement, he undertook a comprehensive metallographic study of the Port Orford specimen to see what could be deduced from the specimen itself. The small specimen provided a surprisingly rich source of interpretable information. As work progressed the conclusion became inescapable to us that the Imilac strewnfield was the source of the bait for the hoax, and our technical paper was written, in a form that we hope will be accessible to the lay reader. Speaking for all three authors, it is our view that the two papers taken together resolve the meteoritic aspects of the Port Orford affair. At the very least, the new information we provide will irrevocably transform the character of any future discussion of the issue.

It is with deep appreciation for a distinguished colleague and friend of many years that I note here that Edward Porter Henderson who was born December 31, 1898 died on September 12, 1992 as these papers were passing through final stages of preparation for publication. Throughout more than 50 years he was intrigued by the Port Orford problem, made important contributions to our understanding of it, and was the Smithsonian's front man in dealing with the public on the issue. Appropriately, the Edward P. Henderson and Rebecca Rogers Henderson Meteorite Fund is partially supporting distribution of this publication to the public.

The Port Orford, Oregon, Meteorite Mystery

1. John Evans and the Port Orford Meteorite Hoax

Howard Plotkin

Introduction

The lost Port Orford meteorite, allegedly discovered by John Evans in 1856, has long puzzled meteoriticists, troubled government officials, and served as a source of adventure for treasure hunters. Contracted by the United States Department of Interior to explore Oregon and Washington territories, Evans claimed that he chipped a small piece off a huge 10-ton boulder on Bald Mountain, one of the rugged Rogue River Mountains in southwestern Oregon. The meteoritic character of the specimen was immediately realized by Charles T. Jackson when he examined it three years later. A noted Boston chemist, Jackson was one of the scientists employed by Evans to analyze his mineral specimens. Jackson hurriedly announced his findings to the Boston Society of Natural History on 5 October 1859,¹ and sent a fragment to W.K. Haidinger, an international authority on meteorites in Vienna, for confirmation. Haidinger verified that it was a pallasite, one of the rarest forms of meteorites, and reported his findings to the Vienna Academy of Sciences.² Distinguished from all other meteorites by their combination of olivine and nickel-iron in subequal amounts, pallasites now constitute approximately only 1.5% of all known falls and finds.³

Jackson enthusiastically wrote Evans, who resided in Washington, D.C., asking him if he could possibly relocate the giant meteorite. Evans replied that "there cannot be the least difficulty in my finding the meteorite," and gave a general description of its location.⁴ In the ensuing correspondence, Evans and Jackson discussed the idea of Evans returning to Oregon to recover the meteorite and transport it to Washington, D.C., as a museum specimen for the Smithsonian Institution.⁵

Howard Plotkin, Department of Philosophy and Department of History of Medicine, University of Western Ontario, London, Canada N6A 3K7.

They then persuaded various scientific academies, including the Boston Society of Natural History and the Academy of Natural Sciences of Philadelphia, to petition Congress to finance such an expedition.⁶ Evans even suggested that these societies themselves might raise the funds to procure the meteorite in whole or in part, should Congress fail to make the necessary appropriation. In return, the meteorite could be cut up into several pieces, with each sponsoring society receiving a sample.⁷

While these plans were underway, however, two events occurred that brought the plans to an abrupt end. On 12 April 1861 Fort Sumter was fired upon, signalling the beginning of the Civil War. And on the following day, Evans unexpectedly died at age forty-nine from a very mild attack of pneumonia.

The timing of Evans' death is rather startling, given that it occurred both unexpectedly and on the day after he received news that would crush all his hopes. Is it possible that he died of apoplexy when he realized that the attack on Fort Sumter doomed any chance of receiving a congressional appropriation? Is suicide a possibility? The only firm details we have regarding his death are those given in Jackson's "Sketch":

We have no doubt that Dr. Evans' constitution was enfeebled by his exposure in that region [at Chiriqui, on the Isthmus of Panama] during the summer months and the rainy season, so as to render him incapable of resisting the very mild attack of pneumonia, which ended his career by death, in Washington, April 13th, 1861.⁸

Although this sounds plausible, the claim that Evans' constitution was somehow weakened during his stay at Chiriqui has been disputed by his great-grandson, Richard X. Evans:

Dr. Evans was charmed by the Chiriqui climate, and intended eventually to move there with his family. He slept out of doors for ten nights in a hammock stretched under a palm roof, with the land breeze passing over a nearby swamp,

without as he said, suffering any inconvenience, and “not a moment’s ill health.”⁹

Without further evidence, therefore, the real cause of Evans’ death must remain moot.

Embroidered in the chaos of war, Congress obviously was in no position to underwrite a costly expedition to recover the meteorite. Moreover, Evans’ death meant that its exact location would never be known. All official efforts to relocate and retrieve the massive meteorite were dropped. But eventually word began to spread that a huge meteorite lay somewhere on an Oregon mountainside near the town of Port Orford, and nearby residents began combing the hills in search of it (Figure 1-1).

This activity intensified when, in 1917, a journal of Evans’ “Route from Port Orford Across the Rogue River Mountains” was found by David Bushnell in New Orleans, where he had tracked down the widow of one of Evans’ sons, Richard J.

FIGURE 1-2 (opposite page).—Evan’s journal entries for 20–22 July 1856. The first of these days was a lay-by day spent at his campsite at the present-day Powers Ranch basin. On the following day, 21 July, Evans specifically mentions climbing Bald Mountain, and describes its position relative to Johnson’s gold mines on a fork of the Coquille River and to the “Great Bend” (i.e., the Big Bend of the Rogue River). This and other evidence helps identify Bald Mountain as Johnson Mountain.

Evans. The journal subsequently was deposited in the Smithsonian Institution¹⁰ (Figure 1-2). Bushnell was an anthropologist with a special interest in American Indians, and a friend of a branch of the Evans family living in Washington, D.C. In the summer of 1929, the Smithsonian dispatched W.F. Foshag, the Curator of Mineralogy and Petrology, to try to find the lost meteorite.¹¹

Searches reached a feverish pitch in 1937, when some Oregon newspapers carried stories that the Smithsonian would reward its finder with up to \$2,000,000. J. Hugh Pruett, an astronomer at the University of Oregon, for example, wrote in

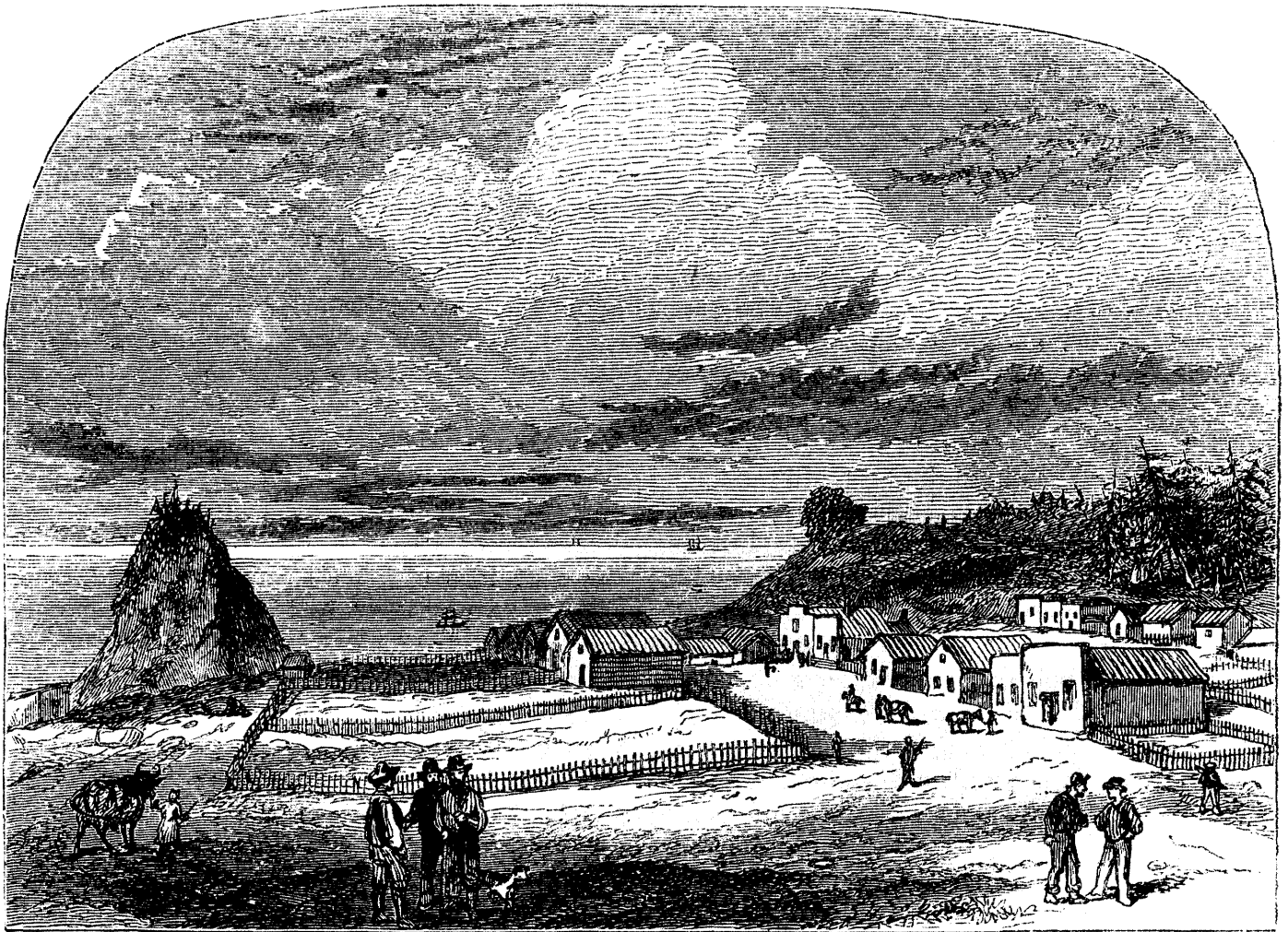


FIGURE 1-1.—Port Orford, Oregon, in its heyday in the 1850s. From *Harper's New Monthly Magazine*, October, 1856.

one mile.

Monday July 20th 1888. Collected a few specimens of grass. Amongst the grasses of this and other prairies is an abundance of mountain clover; the heads are not so large as the cultivated clover; the stalk is about two to two and a half feet high. The soil in this prairie is very good & produces fine vegetables. This prairie is nearly surrounded by high mountains, but there are other similar prairies hidden by tall trees in the immediate neighborhoods, in fact the whole route is through a chain of prairies, some of them several miles long, along ridges covered with fine grass in the deep woods, and occasionally in being from ridge to ridge over high mountains. Noticed to day a tree called chestnut oak, it had seems like the white oak, but the foliage was more like the chestnut than the white oak. at 6. P.M. 41°.

Tuesday July 21st 1888. Started at 7 1/4 A.M. passed along two prairie ridges & woodland to a high and steep mountain estimated at two thousand feet in elevation, collected specimens of the rock along the route, talcose and other slates, gritty sandstone, granite &c. Descended from the valley occupied one hour and a half. The descent to the gold mines of Johnson and others on the Fork of the Loggittie R. also occupied an hour and a half. The descent so much more gradual. The creek at the mines runs through steep mountains covered with timber, a new species of laurel with rare and beautiful flowers. It seems strange to see in full beauty the flowers of early spring

rocks and scattered along your pathway at this season of the year. Passed over a high (Bald) mountain so called, but while of great elevation it is covered at the summit with most luxuriant grass and flowers. Thermometer at 12 m. 69°. Dry creek is bordered by high steep banks (mountains) its bed filled with large boulders of granite, quartz, talcose & other slates, showing it to be to some extent a gold-bearing region. But there is little quartz, either in the rocks or in boulders, and the slate & other rocks, do not as has been discovered, do not contain ^{equal} amount of gold. The distance to the Great Bend is only twelve miles from this place, but we have already visited the head waters of some of its small tributaries and collected specimens on the divide between this Creek & Loggittie River, which indicate the geology with sufficient accuracy. Returned to Bald Mountain camp.

From our last camp to Johnson's diggings we had a mountain to cross at least two thousand feet in elevation. Distance travelled twelve miles.

Started at 7 1/4 A.M. Thermometer at 6. 89 m. 42°. Passed for two miles through woodland rather sparse, in two miles ascended high 'Bald Mountain', overlooking the tops of surrounding mountains for thirty miles or more in every direction, but one where at a distance of ten or fifteen miles is a range of perhaps greater elevation. Amongst the peaks of lofty ranges of rather smooth outline some jagged peaks tower up in bold and rugged grand and

The Sunday Oregonian:

The Smithsonian Institution a few years ago made an offer of \$1 a pound for almost any kind of meteoritic material. Good specimens have sometimes found buyers at \$10, \$20, or even \$100 a pound. The "lost Port Orford" is of the type that usually brings "top prices."¹²

The Smithsonian, of course, had never made such an outlandish offer, but the newspaper accounts spurred hundreds of persons wishing to combine a summer holiday with an adventurous treasure hunt to search for the meteorite. Within two years of the appearance of the newspaper stories, a local Society for the Recovery of the Lost Port Orford Meteorite had been formed (mainly through the efforts of Myron D. Kilgore, a local resident of Lakeside, Oregon) and was initiating searches. In the summer of 1939, the Smithsonian mounted its second search, carried out by Edward P. Henderson, Associate Curator, Division of Mineralogy and Petrology. Like all previous searches, however, Henderson's failed to provide any trace of the meteorite.¹³

The unsuccessful searches did little to dampen the spirits of the meteorite's would-be rediscoverers. By 1964, Hollis M. Dole, State Geologist, Oregon Department of Geology and Mineral Industries, observed that "several dozen parties each year spend many thousands of man hours in this area searching for the Port Orford [meteorite]. This has gone on for at least 50 years."¹⁴ Above all else, searchers relied on Evans' journal for guidance.

Several features of this journal are worth mentioning. Most important is the fact that it is not Evans' original journal, but a copy. That the handwriting is not Evans' is not only my opinion, but also that of handwriting experts at the FBI, who have been sent samples for study.¹⁵ Henderson notes that the journal, written on 12¹/₂ inch by 8 inch paper, is not bound, and points out that "surely an experienced explorer, such as Dr. Evans, would not carry unbound paper into the field to keep notes on."¹⁶ Nor is the journal complete. Words and phrases clearly have been added or deleted in several places; entries for the days between 3–17 July 1856 are missing; and the most famous section, beginning on 18 July 1856 under the title of the journal, is preceded by the words "see section and notes not here copied." Clearly, then, the journal is a transcription, possibly copied from Evans' original notebook(s), now lost, on his return to Washington, D.C. There is no firm evidence as to who transcribed it, but one of Evans' letters reveals that he employed a Clifford Evans (a relative?) as a copyist.¹⁷ These findings do not necessarily compromise the value of the journal, but suggest that it should be used with a certain amount of caution.

Although no mention of a meteorite or anything resembling one is made in the journal, searchers read and reread it for hitherto unnoticed clues, pitting their wits against the available evidence, "urged on by the vague notion that some day the pieces must fall into place, revealing the absolute and true location" of the lost meteorite.¹⁸ Swamped with requests for information on the meteorite and Evans' journal, the Smithsonian began mailing inquirers prepared information sheets

answering the following frequently asked questions:

1. Where can I get a copy of Dr. Evans's diary or account of his journey?
2. Has the government offered a reward for the Port Orford meteorite?
3. Will the government claim the Port Orford meteorite if it is found?
4. I am thinking of flying over the area Dr. Evans explored to look for a crater made by the meteorite. Would this be advisable?
5. Where may I find further information on the Port Orford meteorite?

So enigmatic was the story of the discovery and subsequent loss of the Port Orford meteorite that it had "achieved a status bordering on the mythical for most people."¹⁹

But by this time, 1964, Henderson had come to have strong doubts about Evans' story. His examination of Evans' specimen, which had been acquired by the Smithsonian through a trade with the Boston Society of Natural History in 1920,²⁰ revealed that it was covered in places with "fresh flight crust" showing "delicate markings," that the metal was not battered, and that the olivine crystals were "bright and unusually free from alteration." These features led him to conclude that the specimen "was not removed from a large mass by a hammering operation," as Evans had claimed.²¹ Henderson further pointed out that "it is not an easy matter to break off a piece of a pallasite." Finally, he asked an obvious but particularly bothersome question: "How do you account for the fact that Dr. Evans would comment about granites, talc, etc. [in his journal], and then fail to describe in some detail the most unusual specimen he perhaps ever found in his life?"²²

Believing that searchers were essentially wasting their time looking for the meteorite, Henderson and Dole published a critical paper, "The Port Orford Meteorite," in *The Ore Bin*, the monthly publication of the Oregon Department of Geology and Mineral Industries. In it they reproduced relevant sections of Evans' journal, related Henderson's attempt to retrace Evans' route across the Rogue River Mountains in his 1939 search for the meteorite, and expressed their doubts about Evans' story (Figure 1-3). But so great was the allure of rediscovering the meteorite that their publication did little to deter people from continuing their searches. If anything, it had precisely the opposite effect: "You will be chagrined to learn," Dole lamented to Henderson, "that our article has engendered more activity in the actual search for the Port Orford [meteorite] than it has to curtail it. Oh woe is me!"²³

Few persons seemed prepared to believe that Evans' story was not true. Typically, Evans was defended on the basis of his revered stature as a scientist, and by the fact that he had no reason to lie about his discovery. Ellen C. Sedell, an unaffiliated researcher from Pittsburgh, Pennsylvania, for example, described Evans as "precise and thorough in his work, honest, and a man of integrity," and claimed "we are doing a great disservice to Dr. Evans by doubting his report."²⁴ The late Erwin F. Lange, Professor of General Science at Portland State College, one of Evans' staunchest defenders, typified the feelings of many as he adopted a wait-and-see attitude: "Perhaps, as the search continues and all clues are carefully studied this world famous meteorite may yet be uncovered."²⁵

In the twenty-eight years that have passed since the publication of the Henderson and Dole article, the search for the

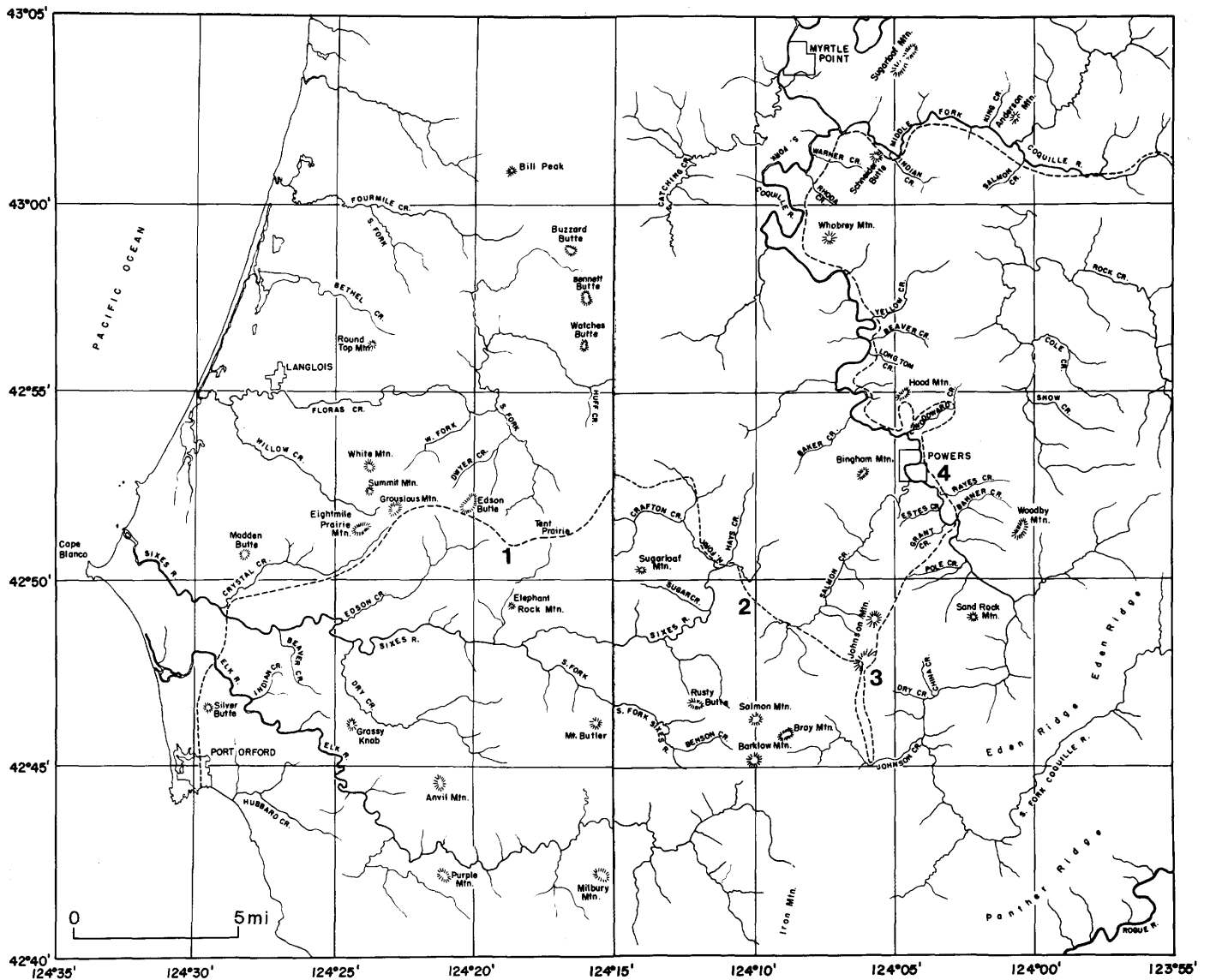


FIGURE 1-3.—E.P. Henderson's and Hollis M. Dole's reconstruction of Evans' route from Port Orford across the Rogue River Mountains in 1856 is shown by the dashed line. Numbers indicate locations of camp sites for the nights of (1) 18 July, (2) 19 and 20 July, (3) 21 July, (4) 22 July. Revised from *The Ore Bin*, July 1964.

lost Port Orford meteorite has continued unabated. Roy S. Clarke, Jr., the Smithsonian's present Curator-in-Charge, Division of Meteorites, bemoans the fact that he has "already had more than one lifetime's worth of correspondence related to the Port Orford meteorite." He goes on, however, to propose a solution: "My best hope for surcease ... is that historians get in there and clean up the mess."²⁶

The author of this study has taken that as his charge. In an endeavor to solve the puzzle of the lost Port Orford meteorite, all of Evans' letters and reports concerning his Oregon explorations on file in the records of the General Land Office and the Office of Explorations and Surveys in the National Archives were examined. So, too, were other letters known to

exist in various government repositories, historical societies, and university archives. Evans' journal was meticulously examined in an effort to reconstruct his route out of Port Orford across the Rogue River Mountains. This route was then compared against those laid down on existing mid-nineteenth-century maps on file in the records of the Office of the Chief of Engineers in the National Archives, on old Bureau of Land Management plats, on old U.S. Geological Survey topographic maps, and on old Forest Service aerial photographs. Evans' "Descriptive Catalogue of Geological Specimens Collected in Oregon and Washington Territory," on file in the Smithsonian Archives, was carefully scrutinized for possible clues (Figure 1-4). This 26-page handwritten manuscript, apparently un-

861	Evans, Geological Survey of Oregon. 1857	No. 255	Hydraulic properties, Anaimo Pancovero Island, no. 2. Limestone (perhaps magnesian) No. 36 Anaimo, 78.
		" 265	Quartz with pyrites; Pancovero Island.
		" 277	Compact trap rock of a basaltic nature Anaimo Pancovero Island.
		" 325	Earthy decomposed ferruginous trap, Anaimo Pancovero Island.
		" 339	Coal, Pancovero Island. (see analysis)
		No. 300	Wm Pettigrew - Earthy sandstone, near Wm Pettigrew.
		No. 109	Johnson's diggings - Serpentine. High mountain 4 miles from Johnson's diggings. No. 20.
		" 306	Similar to 304 ascending high mountain on way to Johnson's diggings.
		" 222	Sandstone ascending high mountain on way to Johnson's diggings.
		No. 304	Decomposing earthy ferruginous trap rock divide between Johnson's mine and R. River.
		No. 116	Oregon near boundary California. Talcous slate, Jacksonville mines, southern Oregon near boundary California.
		No. 150	St. Mary's Valley - Fragment of a ferruginous argillaceous rock St. Mary's Valley. High bank on right of river, 15 m. from Flathead village.

FIGURE 1-4.—Title page and part of Evans' "Descriptive Catalogue of Geological Specimens Collected in Oregon and Washington Territory." Under the heading "Johnson's diggings," the high mountain referred to in the first three entries is Evans' Bald Mountain (Johnson Mountain). None of the rock samples Evans describes here or elsewhere bears even a remote resemblance to a meteorite.

known to Foshag and Henderson, has never before been mentioned in print. Like Evans' journal, however, the "Descriptive Catalogue" is also not an original document, but a copy. On the basis of the handwriting, I am firmly convinced that it was transcribed by Mrs. Evans. While many geological specimens collected in the Port Orford area, even on Bald Mountain itself, are discussed in it, none, however, bears even a remote resemblance to a description of a meteorite.²⁷ Old mining claims also were studied, as were manuscript and printed accounts dealing with Evans and/or previous searches for the meteorite. Several promising areas on the mountain that I identify as Evans' Bald Mountain were searched with highly sensitive proton magnetometers. Numerous attempts were made to track down previously unknown Evans letters, lost manuscripts, and surviving descendants. Prominent contemporary meteoriticists were contacted for their views, and the Port Orford specimen in the Smithsonian Institution was examined.

My investigation led me to the inescapable conclusion that Evans' story was nothing more than an elaborate hoax. In the pages that follow I describe the details of the field searches for the meteorite, assess Evans' stature as a scientist, explain his motivation to lie about his alleged discovery, and reconstruct how he carried out his hoax. Finally, I deal with the last remaining piece of the puzzle, the true identity of the genuine meteoritic fragment that Evans forwarded to Jackson for analysis.

ACKNOWLEDGMENTS

I am grateful to the Social Sciences and Humanities Research Council of Canada for the award of two grants that helped me to carry out field research in Oregon in the summers of 1986 and 1987.

I am happy to acknowledge the great debt I owe to Douglas Borgard, of Bandon, Oregon. During my two field searches with him on Johnson Mountain, as well as afterward, we had countless hours of give-and-take discussion on the intriguing lost Port Orford meteorite. Although it is no exaggeration to say that without his help this paper could not have been written in its present form, I take sole responsibility for the interpretations and conclusions that appear herein.

Because the Smithsonian Institution "has been fortunate enough to have the [Port Orford] specimen and to have had its name associated with the hoax from the beginning," I have found it necessary to call on various persons there time and time again for help in one way or another. Their responses always have been most generous. At the Division of Meteorites, National Museum of Natural History, Roy S. Clarke, Jr. (whose wry comment I quote above), graciously answered a myriad of questions I put to him, made valuable comments on various drafts of this study, discussed them with other interested meteoriticists, arranged for a new polished section of the Port Orford specimen to be prepared for study, and offered helpful advice on various matters relating to publication. It is

my great pleasure to thank him publicly for his constant support and encouragement. On one of my visits to the Division, I was fortunate to talk with the late Edward P. Henderson about his thoughts on, and early search for, the Port Orford meteorite, and to be shown the specimen by Twyla B. Thomas, who shared her knowledge of it with me. At the Smithsonian Archives I thank William A. Deiss, who read an earlier draft of this paper and arranged for me to present my findings in the Smithsonian's "Research in Progress" seminar series, and William Cox, who located much unpublished material and kindly provided me with reproductions.

In addition to the many persons in archives, libraries, government agencies, and universities who generously have aided my research, I would especially like to thank the following: Richard Pugh, Cleveland High School, Portland, Oregon, who generously supplied me with a copy of the late Erwin F. Lange's file on the Port Orford meteorite; Carleton B. Moore, Center for Meteorite Studies, Arizona State University, for his ready responses to my inquiries; Ursula B. Marvin, Harvard-Smithsonian Center for Astrophysics, Robert T. Dodd, Department of Earth and Space Sciences, State University of New York at Stony Brook, and Marc Rothenberg, Joseph Henry Papers, Smithsonian Institution, who offered helpful comments on a draft of this study; Diane Tyler, Editor, Smithsonian Institution Press, whose keen editorial eye helped to clarify the final draft in many significant ways; and Vagn F. Buchwald, Department of Metallurgy, The Technical University, Lyngby, Denmark, whose interest in an earlier draft of this study led him to conduct a new series of investigations on the Port Orford specimen and some of the Smithsonian's Imilac specimens. Insofar as the Buchwald-Clarke study and mine complement and reinforce one another, I am especially pleased that they can be presented together here in this format.

The task of preparing this manuscript for publication has been admirably performed by Nancy Patrick, to whom I am most grateful. Not only has she labored with incredible skill, patience, and good humor, but she also has managed to teach me a great deal about personal computers in the process.

Finally, I would like to thank my wife Donna and my children Rachel, Julie, and Jeremy. Without their love and support, this study would have remained a chimera.

Rationale for a New Field Search

From the earliest stages of the investigation, several things worried me and made me think that something was seriously wrong with Evans' story. Henderson had already given voice to some of these in 1964, e.g., the fact that no mention of a meteorite, or anything resembling one, was ever made in Evans' journal (or his "Descriptive Catalogue of Geological Specimens"), that the Port Orford specimen did not look as though it had been hammered off a large mass, and that it would have been difficult to do this. Even the editors of the *American Journal of Science* alluded to this in an editorial note:

If the Bald Mountain meteoric iron is like in tenacity and hardness to that of most known masses of similar origin, the dissection of it would prove a task of far more difficulty than seems to have been supposed by Dr. Evans.²⁸

In addition to these, I thought of several other reasons why doubt could be cast on Evans' story. In the first place, the sheer size of the meteorite raised alarm. Evans estimated its mass to be 10–11 tons; this would make it by far the largest pallasite discovered at that time, some fifteen times larger, for example, than the famous Krasnojarsk pallasite found in 1749.²⁹ In fact, it would be the twelfth largest meteorite of any kind discovered to date.³⁰ Evans, apparently unfamiliar with meteorite sizes, must not have realized how inordinately large he was claiming the Port Orford meteorite to be. Moreover, due to their composite silicate-iron structure most pallasites do not survive their flight through the earth's atmosphere and/or impact intact, but break up. The Brenham, for example, discovered in 1882, yielded over 5.5 tons of meteoritic material, making it the largest known pallasite to date. But it broke up into more than 2000 fragments, the biggest of which weighed only 454.5 kg.³¹ The largest individual pallasite specimen ever discovered is the Huckitta, found in 1924. Its weight of 1408 kg, however, would make it only one-seventh the size of the Port Orford.³²

Secondly, various descriptions that Evans gave of his discovery of the meteorite conflict so widely as to seem irreconcilable. In one letter, for example, he wrote that there was nothing at all unusual about the specimen, and that he mistook it for a common piece of iron ore: "The small specimen analysed by Dr. Jackson was collected by me as an ordinary specimen of iron ore. I had no idea that it was meteoric."³³ Yet Jackson related Evans' discovery story in very different terms: "The singularity of its appearance caused him to observe very closely its situation, so that when his attention was called to the subject [three years later, when Jackson analyzed it], he readily remembered the position, form, appearance, and magnitude of the mass."³⁴ Additionally, why was there such a long delay between the time of Evans' discovery and Jackson's analysis?

Thirdly, several aspects of Evans' discovery struck me as being excessively opportune. The meteorite's fresh fusion crust indicated that it could not have been in the excessively moist Oregon soil for long, but must have been a rather fresh fall. Had it been an older fall, it undoubtedly would have decomposed or weathered to such an extent that it would no longer attract a collector's notice. But it did attract Evans' attention, because it allegedly was found under the luckiest of all possible circumstances: on a grassy slope, in an area devoid of trees or rocks, on the trail, and on a mountain that was the highest point on his journey from Port Orford across the Rogue River Mountains.³⁵ Of course it could be argued that these were all fortuitous coincidences, coincidences that, in fact, led to the meteorite's discovery, but the odds against this seemed overwhelming to me.

Finally, if everything Evans said about the meteorite were true, how could it be possible that no one else has ever found it? Surely prospectors working in the area at the time of Evans'

discovery would have noticed it, and would have checked it carefully to see if it were a precious metal like silver, or a common piece of iron ore. It further seemed highly unlikely to me that such a large mass could have escaped detection by the hundreds and hundreds of persons who have diligently searched for it throughout the years. Although Evans claimed that the meteorite was found in an area "subject to washings from rains and melting of snow in the spring, so that in a few years these causes might cover up a large portion of it,"³⁶ it is equally possible that these causes might uncover portions of the meteorite, making it more visible. It also struck me that this sounded suspiciously like a convenient excuse for Evans to use if the appropriation from Congress came through and he returned to Oregon to retrieve the meteorite, but came back empty-handed.

In spite of all these doubts, however, there remained the nagging possibility that everything Evans said about the meteorite just might have been true, that all of the above-mentioned fortuitous circumstances did, remarkably enough, lay behind his discovery, and that a massive 10-ton pallasite was actually lying on Bald Mountain, waiting to be rediscovered. Although I judged the odds for this to be slim, I felt that a field search on Bald Mountain was essential to the effort to solve this 136-year-old mystery.

Identification of Bald Mountain

Before beginning the search for the meteorite, it was first necessary to identify which mountain was Evans' Bald Mountain. Evans' letters to Jackson contained several clues. In one letter, for example, he wrote:

The western face of Bald Mountain, where it [the meteorite] is situated, is, as its name indicates, bare of timber, a grassy slope, without projecting rocks in the immediate vicinity of the meteorite. The mountain is a prominent landmark, seen for a long distance on the ocean, as it is higher than any of the surrounding mountains. ... It is situated in a mountainous region, thirty to thirty-five miles from the coast, and the only access to it is by mountain trails.

Evans also mentioned in this letter that a river "passes the base of the mountain, and empties into the Pacific." One final tantalizing piece of information also is contained in this letter. Evans stated: "It would doubtless be best and most economical to make a preliminary visit [back] to the locality, accompanied only by the two voyageurs alluded to in my last letter." Because these two voyageurs had accompanied Evans on his expedition, they presumably also would have seen the meteorite Evans claimed to have found, and thus possibly could provide invaluable information concerning its location. Although Jackson did not relate any details from Evans' last letter, he parenthetically did say that they were "two of the Canadian Frenchmen in the employ of the Hudson Bay Company."³⁷ Unfortunately, however, it has not been possible to unearth any information about these two voyageurs, so this information provides no help in identifying Bald Mountain.

A few additional details are provided in a second letter: "The

locality is about forty miles from Port Orford, in the mountains which rise almost directly from the coast, only accessible by pack mules."³⁸

As explicit as these details seem, they do not, unfortunately, provide sufficient information to make a positive identification. In Evans' time, "Bald Mountain" was a general term indiscriminately given to any unnamed mountain having a high grassy prairie. This has led one observer to comment:

There is probably a Bald Mountain in every county in the state, and more than one in some. The ease with which this descriptive name was applied does not speak well for the geographic imagination or ingenuity of early settlers.³⁹

More information is therefore necessary in order to conclusively determine which of the Rogue River Mountains is the one that Evans was referring to.

Evans' journal provides this necessary information (Figure 1-2). In it, he relates that on the afternoon of 19 July 1856 he "crossed two or three small creeks, forks of Sixes River, camped at 5 p.m. on a small creek tributary of Salmon River [sic]."⁴⁰ There can be little doubt that the location that Evans described is that of the present-day Powers Ranch basin. Moreover, because he estimated that at this point he had travelled 39 miles since leaving Port Orford, this would have placed him very near his 40-mile estimate of the location of the Bald Mountain on which he claimed to have found the meteorite (Figure 1-3).

The following day was a lay-by day, during which Evans "collected a few specimens of grass," but did not travel. On the next day, 21 July, he specifically mentions climbing Bald Mountain:

Passed along two prairie ridges and woodland to a high and steep mountain estimated at two thousand feet in elevation. . . . Passed over a high (bald) mountain so called, but while of great elevation it is covered at the summit with most luxuriant grass and flowers.

After crossing the mountain he descended "to the gold mines of Johnson and others on the fork of the Coquille R[iver] Abbott's branch" (Figure 1-5). Evans estimated that these mines were 12 miles from the "Great Bend" (i.e., the Big Bend of the Rogue River, near the present town of Illahe). From this description it is clear that the "fork of the Coquille" being mined was Johnson Creek, and that Evans' "Bald Mountain" is Johnson Mountain. Both Johnson Creek and Johnson Mountain had been named after "Coarse Gold" Johnson, who discovered rich nuggets of gold in the creek in 1854.⁴¹

Additional support for this identification is furnished by Evans' description, given the following day, of his view from the summit of Bald Mountain:

Overlooking the tops of surrounding mountains for thirty miles or more in every direction except perhaps one where at a distance of ten or fifteen miles is a range of perhaps greater elevation. Amongst the ocean of lofty ranges of rather smooth outline some jagged peaks tower up in bold and rugged grandeur.

This perfectly describes the panoramic vista from the lookout knob on Johnson Mountain at an elevation of 2941 feet, some

2121 feet above the Powers Ranch basin. On clear days the Pacific, some 30 miles to the west, can be seen from this summit.

Still further corroboration is provided by Evans' description of his route after leaving the summit:

Our route continued along a high ridge, of which the peak just referred to is a part, passed through several prairies similar to those previously noted . . . passing down into the valley we crossed the river. Spent three hours looking for trail to Enchanted Prairie.

On the basis of this it is possible to retrace Evans' route as he followed the ridgeline north of the lookout knob, descended Johnson Mountain between Pole Creek and Grant Creek, and went north along the Coquille in the neighborhood of the present town of Powers looking for the trail to Enchanted Prairie (on the Middle Fork of the Coquille, between the present towns of Bridge and Remote).

Finally, Johnson Mountain meets perfectly all of the criteria for Bald Mountain provided in Evans' letters to Jackson. Namely, it is about 30 to 35 miles from the coast and about 40 miles from Port Orford, it is higher than the surrounding mountains, it is visible from the ocean, there are grassy prairies on its western face, and there is a river that passes its base and empties into the Pacific. No other mountain completely meets all of these criteria. It is virtually certain, therefore, that Johnson Mountain is the Bald Mountain on which Evans claimed to have found the Port Orford meteorite.

Author's Field Searches

My field searches on Johnson Mountain were carried out in conjunction with Douglas Borgard, a native of nearby Bandon, Oregon. When I first contacted him in the spring of 1986, he already had spent several years researching the Port Orford meteorite story, and had, despite his youth, acquired the reputation of being the person who probably knew more about it than anyone else. In preparing for our field work, we took note of the fact that Johnson Mountain already had been the object of serious searches by Myron D. Kilgore of the Society for the Recovery of the Lost Port Orford Meteorite, and by E.P. Henderson of the Smithsonian Institution. It is interesting to note that although the first Smithsonian search carried out by Foshag had centered on Iron Mountain, he afterward felt "inclined to believe that Johnson Mountain is the place."⁴² We also were aware that hundreds of holiday adventurers had searched the area, and that various portions of the mountain had been logged since the 1950s. This led us to believe that if the meteorite were there, it must be hidden from view, either covered by vegetation or, worse, buried under feet of dirt by a mountain slide. We therefore decided to use magnetometers to aid us in our search.

The particular instrument we chose was the proton magnetometer, so-named because it utilizes the precession of spinning protons or nuclei of the hydrogen atom in a sample of

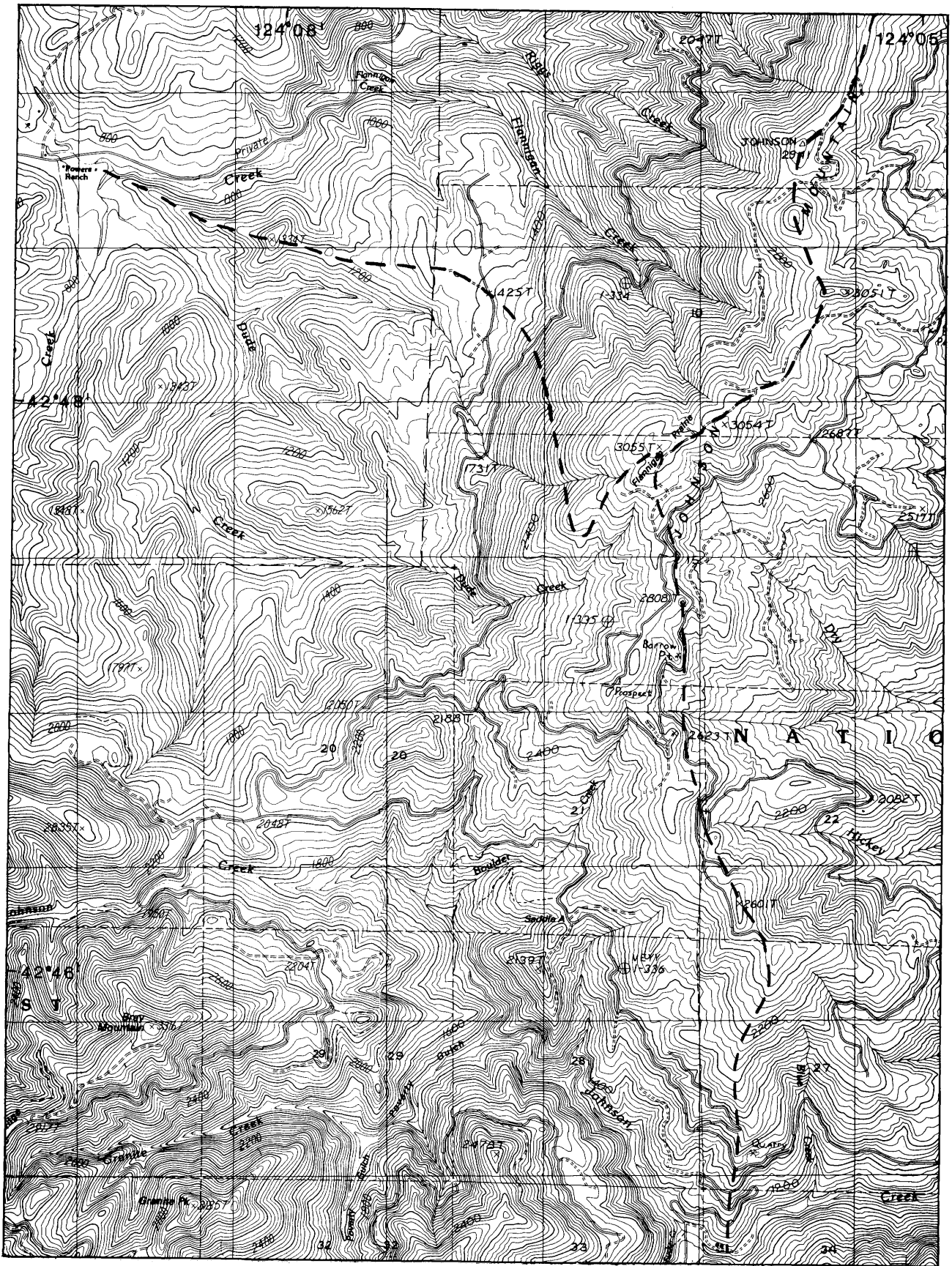


FIGURE 1-5 (opposite page).—The author's reconstruction of Evans' route from the Powers Ranch basin over Bald Mountain (Johnson Mountain) to the gold mines on Johnson Creek is shown by the dashed line. Evans' route back over Johnson Mountain on his way toward present-day Powers is also shown. From U.S. Geological Survey 7.5 minute topographical maps, Barklow Mountain and China Flat Quadrangles. Width of map shows a distance of 3.75 miles.

hydrocarbon fluid to measure magnetic intensity.⁴³ Highly sensitive and very portable, these instruments have been used successfully to find such diverse buried objects as pipelines, survey benchmarks, archaeological pottery and tombs, aircraft flight recorders, and even skiers buried in avalanches. For our search procedure we decided to use parallel traverses, spaced 30 feet apart, taking readings every 30 feet. Based on the assumption that the meteorite would be a typical pallasite, and hence contain about 50%, or five tons, of iron, we figured that if the meteorite were hidden on the surface, it would produce an anomalous magnetic intensity reading of at least 3000 gammas; if buried at, say, 20 feet, at least 900 gammas.⁴⁴

Our magnetometer searches on Johnson Mountain, the first ever conducted there, were carried out during portions of the summers of 1986 and 1987. In 1986 we limited our investigation to some promising areas on or near the top part of the mountain, specifically the lookout knob, Flannigan Prairie, and the area near the southern summit. The first two of these areas are large grassy prairies that extend down the western face of the mountain, whereas the southern summit shows evidence that it might have contained some grassy areas on its western face in Evans' time. Since the time of our initial search, however, closer analyses of the number of growth rings of the tree stumps on the western face of the southern summit have convinced us that the small size of the trees there is more a result of stunted growth than young age. Consequently, we do not now believe that the southern summit area could have been a prairie in Evans' day. Because all three areas were either on or near the old trails,⁴⁵ moreover, they seemed to meet the main criteria for the location of the meteorite.

Although we encountered several minor magnetic anomalies in our search, the greatest ones, some of which were a few thousand gammas, occurred in the region of the abandoned White Rock Chromite Mine.⁴⁶ Although they caused considerable excitement at first, we became convinced that these high readings were due to the general magnetic properties of the rocks and soil there, not to a single magnetic anomaly. They occurred because chromite, itself usually nonmagnetic or only very weakly magnetic, is often found in the presence of magnetite. And magnetite, which originates from processes of serpentinization, produces magnetic anomalies.⁴⁷

Our 1987 field work centered mainly on the ridgeline leading out of the Powers Ranch basin to the high, steep face of Johnson Mountain below Flannigan Prairie. The large grassy area from this ridgeline south to Tim Creek is known as Panhandle Prairie. This area seemed especially promising for several reasons. In the first place, there is some evidence that

the earliest trail out of the basin to Johnson Mountain and the Johnson Creek mines was via this ridgeline.⁴⁸ Secondly, Evans specifically mentions in his journal that he followed two "prairie ridges" out of the Powers Ranch basin to a "high and steep" mountain. Although it also would have been possible to approach Johnson Mountain via the Tim Creek ridgeline, the presence of well-established trees there does not support the idea that it could have been a prairie ridge in Evans' day (Figure 1-5). Moreover, the Tim Creek ridgeline does not lead to a particularly "high and steep" section of Johnson Mountain. Thirdly, whereas Evans' description in his 1 May 1860 letter to Jackson of the western face of Bald Mountain as being "bare of timber, a grassy slope, without projecting rocks" perfectly describes the entire region of Panhandle Prairie, neither Flannigan Prairie nor the lookout knob prairie is devoid of rocks. Finally, the fact that Evans voiced a concern in one of his letters that the meteorite might become buried by debris washing down on it from above⁴⁹ clearly implied that it was not located on or even very near the summit, but at some distance below it.

Together, all of these factors seemed to indicate that the western prairie elevations of Johnson Mountain were even more favorable search areas than those of the previous year. The magnetometer readings in this entire area, however, were incredibly flat. Lastly, we examined a small, high prairie a short distance southwest of Flannigan Prairie that we did not search the previous summer. But once again, the results were negative.

Combined with my earlier doubts, the failure of our field work to uncover any trace of the meteorite seemed to me *prima facie* proof that in some crucial ways Evans' story could not be true. But without further supporting evidence I was reluctant to positively conclude that the whole story was nothing but a hoax. I therefore decided to do further research on Evans, and to go back over all of his correspondence and notes, searching this time not for clues to the meteorite's location, but for evidence betraying a hoax. This new research produced startling results: it indicated that Evans was ill-trained for his work, which was superficial and unprofessional in its execution; that he ran into insurmountable debts, and then gambled on receiving supplemental congressional appropriations to help cover those debts; and that his travels through the Isthmus of Panama provided him with the opportunity to acquire a meteorite specimen.

Evans' Stature as a Scientist

Details about Evans' early life are somewhat sketchy. Born on 14 February 1812 in Portsmouth, New Hampshire, he was the son of Richard Evans, an associate justice of the Superior Court of New Hampshire, and Anne Wendell (Penhallow) Evans, the great-granddaughter of Chief Justice Samuel Penhallow, who had emigrated to New England from Great Britain in 1686. His early education was in the public school system of Andover, Massachusetts. In 1831, at age nineteen, he

moved with his family to Washington, D.C., where he worked as a clerk in the general Post Office Department for eight years. On 16 May 1835 he married Sarah Zane Mills, the daughter of Robert Mills, the architect of the Washington Monument, and Eliza Barnwell (Smith) Mills, the daughter of General John Smith of Hackwook Park, Virginia, a Revolutionary War patriot.⁵⁰

In 1839, Evans and his young family (there were three sons and a daughter, but their birthdates are not known) moved to St. Louis, Missouri. He studied medicine at the Medical Department of the St. Louis University, but there does not appear to be any evidence that he ever earned a medical degree. Although he frequently was referred to as Dr. John Evans during the period 1851–1853, this simply may have been the result of a somewhat grandiose affectation on his part. In 1854, however, he was awarded an honorary medical degree. He was informed of this fact by A. Litton, a chemist at the St. Louis University who apparently was close to Evans and later analyzed many of the geological specimens he collected. But it is revealing that the degree apparently was granted not in recognition of Evans' studies, but rather as an attempt to stabilize his reckless ways:

It may not be uninteresting to you to know that at the last commencement of the Medical Department of the St. Louis University the honorary degree of Doctor of Medicine was conferred on you. ... I now hope you will quit your roaming habits, & settled [sic] down in some civilized country & practice medicine & Christianity.⁵¹

The historical portrayal of Evans as a well-trained scientist who did excellent field work in a professional manner and who was highly regarded by his peers does not stand up to close scrutiny. In many ways, Evans was poorly qualified to carry out the geological surveys for which he was commissioned. He was not a geologist by profession or training. There is no evidence that he knew anything more about geology than any interested and intelligent layman.

Evans' geological career began in 1847 when David Dale Owen, a superb field geologist, appointed him as a sub-agent on his four-year geological survey of Wisconsin, Minnesota, Iowa, and part of the Nebraska Territory. It is not clear why Evans was chosen for this task. Perhaps Litton had a hand in this for he also was a member of Owen's expedition.⁵² In 1849, as Evans was traveling high up the White River, he came upon the extensive fossil remains of the South Dakota Badlands (or Mauvaises Terres, as they were then called by French Canadian trappers). Evans was the first scientist to explore and report on this rich and very important fossil deposit. His report, published by Owen in 1852, attracted wide attention and gave Evans his first measure of credibility as a scientist.⁵³

Following his return, Evans was appointed by the Department of the Interior in 1851, largely on Owen's recommendation, to explore the geology of the Oregon Territory. After his first trip to Oregon (see below), as he was preparing to return there in the spring of 1853, Evans received an offer from I.I. Stevens, the newly appointed Governor of the Washington Territory, to serve as the geologist of a Pacific Railroad survey

he was leading. Although the purpose of Steven's survey and related ones was to explore routes for the proposed railroad from the Mississippi Valley to the Pacific coast, nearly all such surveys included one or more geologists or naturalists. Stevens was well aware of the fact that Evans was on his way back to Oregon in connection with his work for the Department of the Interior, and felt that he was therefore in a position to render him valuable cooperative aid:

I am desirous there should be the most entire cooperation between yourself and my expedition, so that our mutual labors shall promote in the most effective manner the object we have in view. This can only be done by your becoming the geologist of the expedition.⁵⁴

Evans accepted this offer, and was informed by Stevens that he would be paid \$2000 for his labors, and be given an additional \$500 to hire an assistant.⁵⁵ Evans then proposed that he return to the Badlands on his way to Oregon in order to collect fossils as part of his work for the Pacific Railroad Survey.

Evans' behavior during this expedition reveals that he had scant regard for traditionally accepted professional norms. As he was preparing for this trip to the Badlands, F.V. Hayden and Fielding B. Meek, both leading geologists of their day, were preparing for a similar expedition to the Badlands. On learning this, Evans did everything in his power to disrupt their expedition. Meeting them in St. Louis he told them he was "violently opposed" to their proposed trip and attempted to keep them from leaving, claiming that they were poaching on his discovery. He then tried to break up their expedition by hiring Meek away as his own assistant. A heated exchange ensued, "which was finally resolved by the forthright honesty and patience of Meek and the good offices of George Engelmann [a St. Louis physician who had a special interest in botany] and Louis Agassiz [the highly regarded Swiss naturalist from Harvard who became the principal American opponent to evolution], who happened to be in St. Louis at the time."⁵⁶

Meek was distressed by this "extremely unpleasant" state of affairs, but the matter did not end there. As Hayden's party and Evans' steamed up the Missouri River together, Evans unexpectedly left the boat at Council Bluffs, saying he would go on to Fort Pierre by horseback, and meet them there. At first Meek was at a loss to know what Evans' object was, but he soon figured it out:

Evans says he will not leave the Fort until the boat comes, but I would not be astonished if he would push immediately on to the Bad Lands and leave Shumard [Benjamin F. Shumard, a physician who had previously worked with Evans on Owen's survey and was now serving as Evans' assistant] to come on with his provisions. If so, he will be there a few days ahead of us.⁵⁷

Although Hayden and Meek briefly considered beating Evans at his own game by racing him to the Badlands on horseback, they feared the risk of doing so: "As this would only stimulate Evans to greater exertions, we concluded we had better not do so, especially as he could employ a strong force at the fort, if he so chooses."⁵⁸

The results of Evans' 1853 trip were disappointing. Many of

the fossils he collected were sent to Joseph Leidy in Philadelphia for study. Leidy, a professor of anatomy at the University of Pennsylvania and one of the greatest naturalists in America in the last century, characterized the collection as a hodgepodge weighing “nearly two tons, of which 800 lbs. consist of uncharacteristic fragments, eventually to be thrown away as utterly worthless.”⁵⁹

Evans never published these findings, or any other, from his work on the Stevens survey. Two final reports were supposedly lost in transit to Washington. A *House Executive Document* states that Evans’ report of his

route south of the Missouri and Yellowstone, and between the Milk and Missouri Rivers ... sent from Washington Territory, where Dr. Evans was still employed in the field when the report of Governor Stevens was submitted, was lost on the route

and that his “route from Fort Benton to the lower Columbia” was likewise lost.⁶⁰

Disclosure of this in the official congressional report caused Evans “much anxiety.” At first he denied that there had been any lost reports. He argued that by giving Stevens such things as copies of his maps showing the various mountain passes and trails, information on suitable depot points and the best way to travel between them, and his barometrical observations, he had fulfilled all of his contractual obligations.⁶¹

This was not a defensible position, however. Stevens had specifically charged Evans with the task of preparing “the geological paper for my report.”⁶² Eventually Evans admitted this, and that he had, in fact, failed to meet this charge. He now tried to argue that the fault was not his, however. Prior to the expedition he had written a set of instructions to help Stevens’ assistants in their geological collections.⁶³ But they had let him down badly, he claimed:

The result of all the collections of his various parties, and the report thereon, I had the honor to submit to you on Saturday last, in a ticking sack 20 inches long by 2 inches in diameter, together with a report from Dr. Suckley [George Suckley, appointed as an assistant naturalist], of seven lines in length. I could not make a report out of nothing.⁶⁴

This claim, while it may well have been true, is not the real reason why Evans did not produce a final written report for Stevens. For in the very next paragraph of this letter, he states that

I had in previous explorations examined all the passes explored by Gov. Stevens’ parties; and made geological collections along the route. But did not conceive it to be my duty to turn over to Gov. Stevens this information on his failure to pay the expenses as agreed upon.⁶⁵

This clearly reveals that Evans did, in fact, have sufficient material at hand to compile a report for Stevens, but failed to do so solely for financial considerations.

Evans’ surviving geological notes from this expedition, kept in his journals, show that although he was an accurate describer, his analysis was cursory. George P. Merrill, the Curator of Geology at the Smithsonian from 1897 to his death in 1929, characterized Evans’ notes as follows:

The geological notes with all [geological] sections missing are of little moment,

consisting mainly of references to the lithological character of the rocks observed with little concerning dip or strike, and nothing relative to their fossil contents.⁶⁶

These kinds of difficulties, i.e., superficial field work, unprofessional conduct, and financial problems, were in evidence from the beginning of Evans’ career, and would continue to plague him throughout. In the end, they would consume him. Viewing Evans in this new light made a hoax scenario much more palatable to my mind.

Motivation for the Hoax

Just as the portrayal of Evans as a revered scientist did not stand up under close scrutiny, neither does the assertion that he had no reason to lie about his discovery of the meteorite. In fact, he had a compelling reason—a desperate need for money. That Evans would run into serious financial difficulties was apparent almost from the beginning. In 1851 he was appointed by the Department of the Interior “to commence a Geological & Mineralogical Survey West of the Cascade Mountains in Oregon Territory, beginning with the main lines for the public Surveys.”⁶⁷ Before commencing, he had outlined to J. Butterfield, the Commissioner of the General Land Office, not only the extent of what he proposed to survey, but also how he wished to be paid:

As to the expense of the reconnaissance, I am willing to undertake it with the means at the disposal of the Department: trusting that if after the exercise of the most rigid economy, the expense should be greater than the amount now applicable to the survey, that the Government would provide for the deficiency by future appropriations.⁶⁸

Although the commissioner agreed fully with Evans’ proposed extent of the survey, he made no promises, explicit or implicit, that the government would provide for any deficiency. Rather, he pointedly told Evans that he would be paid “six dollars per day, and ... necessary expenses en route,” and that his accounts would “be rendered in the usual mode, with which you are already familiar.” The bottom line was that Evans had to keep “within the limits of the means which the Department has the power to devote to the purpose in view, viz. thirty five hundred dollars.”⁶⁹

In spite of these explicit instructions, Evans did not keep his costs within the stated budget. By July, only four months later, he wrote from Oregon that he would not return to Washington, D.C., at the beginning of the rainy season, as planned, but would stay on until the following rainy season. As a result, the cost of the survey would almost triple to \$10,000, but he gambled on his “trust that Congress will make the necessary appropriation.”⁷⁰

Although he received no promise that any supplemental appropriation would be forthcoming, Evans decided the following summer that he would remain in Oregon “until further instructions are received from the Department.”⁷¹ He finally returned to Washington, D.C., in December 1852. Shortly thereafter, in March 1853, Congress appropriated an

additional \$16,984; \$11,984 “for expenses incurred in a geological survey of Oregon,” and an additional \$5,000 “to complete the reconnaissance.”⁷² Evans’ gamble had paid off. In April he was instructed to return to Oregon to complete his survey.

This time Evans remained in Oregon for little more than a year, returning to Washington, D.C., in the fall of 1854. During this trip he spent all of the newly allotted budget, and ran up another large deficit. This was unavoidable, he claimed, due to such diverse factors as the extremely high prices of goods and services in the wilderness, the difficulties of transportation, and the mountainous character of the country explored.⁷³

In March 1855, Congress appropriated another \$23,560 for Evans’ survey; \$5,692 to cover his incurred expenses over the \$5,000 he had been allotted previously, and an additional \$13,000 to complete the work.⁷⁴ Armed with this, Evans made a third trip to Oregon between May 1855 and the fall of 1856. Once again, however, he exceeded the amount appropriated, this time by \$3,574.

In addition to this new deficit, Evans informed the General Land Office in the fall of 1857 that his final report, the *Geological Survey of Oregon and Washington Territories*, would be “about two thirds the size of Dr. Owens’ [sic] report; and will cost, if published in the same style, \$26,526, including the cost of preparing all the maps and other illustrations.”⁷⁵ This amount included \$7,500 he claimed he owed to the various assistants he had hired to perform soil and mineralogical analyses, and to draw maps and illustrations.⁷⁶ In short, after appropriations totalling \$44,044 for his Oregon survey, which originally had been budgeted at only \$3,500, Evans was now seeking an additional \$30,100 appropriation (including his deficit). This staggered the General Land Office, which claimed that there simply was “no means applicable under existing laws” to meet this expense.⁷⁷

Evans’ \$3,574 Oregon deficit, when combined with the \$7,500 he owed his assistants, brought his personal debt to \$11,074. Evans must have realized that there was no way he could recoup this money outright. His only hope was to link his personal debt with the projected expenses for the publication of his final report, and hope that Congress would pass a supplemental appropriation bill that would cover everything. But the amount involved was so great that this seemed beyond hope. Evans’ letters show that his personal debt weighed heavily on him throughout the remainder of 1857, and grew more and more oppressive as the sought-after appropriation bill repeatedly failed to pass Congress.

As if these financial worries were not enough, he faced others as well. While on his western exploring trips, Evans had borrowed money to speculate on land. Beginning as early as 1853, he had purchased lots in Oregon City, a rapidly growing political and trade center; and Albany, Oregon; and Olympia, the capital of Washington Territory.⁷⁸ Although Evans claimed that he had borrowed the money to “pay off my men and the other expenses,” it is possible that his “other expenses” included his land purchases. Most of the lots had been bought

during the Indian Wars, when there was a depression in the value of property, and Evans had anticipated a handsome return on his investments. But due to the recent discovery of gold in the west and the resultant “mining mania,” many persons were now anxious to sell their property cheaply in order to raise quick money to outfit expeditions. Property prices had gone down, therefore, not up. There is evidence that the interest he owed on his loans now amounted to \$1,350, and was increasing at a rate of three percent per month.⁷⁹ Evans’ financial situation was obviously of very serious concern to him.

In February 1858, Evans wrote Meek that the “want of funds ... to pay necessary expenses and to complete my report render it necessary for me to raise money immediately.”⁸⁰ He then revealed that he had bought two blocks of land in Olympia, containing eight lots each, and offered to sell him a block for \$1,000. When Meek turned down this offer, Evans asked him if he would loan him the \$1,000 at two percent per month, to be secured by a mortgage on the Olympia property.⁸¹ When this offer, too, was turned down, Evans felt he had no option but to return to Oregon to raise money by selling some of his property. Before leaving, he submitted his completed *Geological Survey* to the General Land Office in May.⁸²

Arriving in Oregon City in October 1858, he found the situation even worse than he had feared. He estimated that his holdings had decreased in value by more than 50%, and he was able to sell only one lot. This meant that he now would have to mortgage the Olympia property cheaply. In a letter to his wife, he bleakly assessed his prospects: “Dear wife I have not very strong hopes of success this winter before Congress. And if I fail again shall be almost inextricably involved.”⁸³ The thought of returning to Washington, D.C., and battling Congress for the appropriation necessary to publish his report was so depressing that he considered giving up the fight entirely: “My own judgement is very decided that it would be for our future interest to settle on this coast, both for ourselves and children.”⁸⁴ He had ascertained that the office of Register of the Land Office for Oregon was vacant, and urged his wife to get all their friends “working together” to help him obtain it. Evans was despondent, and had just about given up all hope. He proceeded overland to San Francisco by way of Yreka, where he hoped he could collect a debt owed him from an earlier cattle sale, took a steamer to the Isthmus of Panama, crossed it, and caught another steamer for the trip up the east coast.

By the time Evans had made his way back home to Washington, D.C., in December, however, his outlook had changed dramatically and he was surprisingly buoyant. He felt “better prepared to ‘wage war’ with Congress” than ever before. Moreover, “matters in other respects also look more favorable.”⁸⁵ Evans did not give any reasons for this sudden change in outlook, or specify what the “matters in other respects” were. What he did mention, however, is that during this trip (made entirely at his personal expense solely to raise money by selling some of his property, some six to seven months after the submission of his *Geological Survey* to the General Land Office) he had “made some interesting additions”

to his geological collection.⁸⁶ Indeed he had! It is my contention that Evans had acquired a small but very rare piece of meteorite, and had hatched a scheme whereby he could use it to turn around his financial affairs and extricate himself from the hole he was in.

Reconstruction of the Hoax

The first announcement of the meteoritic nature of the Port Orford specimen was made to the Boston Society of Natural History on 5 October 1859 by Charles T. Jackson. The very fact that the analysis had been made by Jackson is virtual proof that the specimen had not been collected during Evans' 1856 explorations in Oregon, as his journal's itinerary implies and his letters claim, but during his 1858 trip. All of Evans' geological specimens collected during his 1856 trip, as well as his earlier ones, were analyzed by A. Litton.⁸⁷ Litton had completed his work by March, 1858.⁸⁸ Seven months later, while in Oregon, Evans learned that Litton's wife had died, and that he would no longer be able to work for him: "Poor Dr. Litton has lost his wife—his first love. He is almost broken hearted and disconsolate and writes me that he has been wholly unable to do any work since."⁸⁹ It was then, and only then, that Evans turned to Jackson to analyze his newly acquired specimens.⁹⁰

It seemed totally inconceivable to me that Evans simply could have made a mistake about something as recent and fundamentally important to his story as the date of his discovery of the meteorite. I therefore took this to be a deliberate lie on his part. More than anything else, this led me to suspect that his whole story was a hoax.

Evans' description of the huge 10-ton parent mass from which he claimed he had broken off the Port Orford specimen intrigued Jackson: "Dr. Evans assures me that the Oregon meteorite is of large size & of great value to science." In addition to its scientific value, Jackson alluded to the meteorite's strong nationalistic and immense financial value:

I am afraid that if some measures are not taken by the U.S. Government to secure this specimen that it will become a subject of private speculation on the part of foreigners, for it is well known that rare meteorites sell for their weight in gold in Europe.⁹¹

To prevent losing the meteorite to a European collector, Jackson proposed that it be procured by the United States Government. He went on to suggest that it should be placed in the Smithsonian Institution, "where it properly belongs":

I have proposed the Smithsonian Institution as the place of deposit for this very valuable meteorite in hopes that Congress will make an appropriation of the money needed to place it there & also because I think the Smithsonian is at the head of our meteorological institutions & should have charge of some of the solid things which rain down from above.⁹²

This suggestion played perfectly into a scheme that I believe Evans was in the process of developing, and perhaps even gave shape to it.

Joseph Henry, the Secretary of the Smithsonian Institution,

however, saw its primary role as that of a research institution, and was unwilling to commit its limited income to museum development. For this reason, he made no effort to emulate the meteorite-collecting activities of the European museums. Whereas this undoubtedly meant that he would not consider providing Smithsonian funds as an alternative to congressional funding to retrieve the Port Orford meteorite, it did not mean that he would refuse it if it were offered as a gift. It should be noted that Henry did, in fact, do some collecting; under him the Smithsonian acquired sundry collections from various Land Office surveys and exploring expeditions, including many objects from Evans himself. Furthermore, Henry did have an interest in meteorites, as witnessed by the fact that he supported research by J. Lawrence Smith on the meteorites in the mineral collection bequeathed by the institution's benefactor, James Smithson.⁹³

While Jackson was busy analyzing the meteorite, sending off a piece to Vienna for confirmation, and relaying letters from Evans to the Boston Society of Natural History, Evans was also busy. He played an active role in persuading various academies to petition Congress to finance a recovery expedition, and implored them to exert all the influence they could muster to accomplish this goal:

It would aid materially in accomplishing the object in view to have copies of the memorial sent to the President of the Senate and the Speaker of the House. It would also be well to send a copy to the Secs. of War & Interior Department who have both been addressed by the Natural History Society of Boston, and by Prof. [Alexander Dallas] Bache of the Coast Survey & Prof. [Joseph] Henry of the Smithsonian Inst. It would also be well to address some members of Congress on the subject ... who may be on friendly terms with some member of your Society or be a lover of science.⁹⁴

Unfortunately, Henry's correspondence in this regard was lost in the 1865 fire at the Smithsonian that destroyed almost all of its holdings; this prevents us from knowing the precise extent of his support at this time. The feverish activity on Evans' part, however, makes it abundantly clear how urgently he wanted Congress to make an appropriation for the meteorite's recovery.

Why was he so anxious to bring this about? Evans had by now given up all hope that Congress would pass a \$30,100 supplemental appropriation bill for the publication of his final report: "The funds of the Government are so low that it is very hard to obtain an appropriation for any purpose except the current expenses of the Depts. and Congress."⁹⁵ But he had thought of a clever scheme whereby the meteorite could be used to get around that.

Evans' plan is revealed in a letter to Leidy (Figure 1-6). After

FIGURE 1-6 (following pages).—Evans' letter to Joseph Leidy, 25 November 1859. This letter, in Evans' own handwriting, not only describes the meteorite, its location, and the excitement it had already aroused, but also reveals his plan for carrying out the hoax. By linking together the idea of a modest appropriation to retrieve the meteorite with the much larger appropriation necessary for the publication of his final report, Evans hoped he could slough off the latter as a current expense. He had by now become so desperate to secure funds for this that he vowed "we must leave no stone unturned."

W. W. C. W.

Dr Joseph Seely

Washington Nov. 25th 1859

Dear Sir,

Enclosed herewith I send you two communications from Dr. Chas. J. Jackson of Boston, Mass, in relation to a meteorite discovered by me in the Roque R. Mts. near Port Poford. It has excited much attention in the 'Boston Society of Natural History', and communications have been addressed by that body to the Sec^y, War, Sec^y Interior, Com^{rs} Genl Land Office, Prof Henry Smithsonian Instⁿ and to Genl Stevens and Prof Drake, also to prominent members of Congress. The object in view is, if possible, is to enable me to secure the whole Meteor, and if that is not practicable to secure large specimens for the different Scientific Societies in the U.S. & Europe and to dig around and under the Meteor and make accurate drawings and measurements of the same. Will your Society aid my views in this matter? The Meteor is located on the face of a 'bald Mt.' a prominent land mark seen from the Pacific Ocean for a long distance, and is about 400 miles from Port Poford, a regular landing port for the Pacific Mail Steamers. The small specimen analysed by Dr Jackson was collected by me as an ordinary specimen of iron ore. I had no idea

That it was meteoric. It projected from the M^t about
 four or five feet, and was about the same dimensions in
 width & thickness, but no doubt a large portion of it is
 buried beneath the soil. The annual accumulation of vegetable
 matter brought down by melting snow and rain storms would
 tend materially to cover it up, as well as the force of the descent.
 The plan is to make every possible effort to induce Congress to
 make the necessary appropriation. And if this should prove
 unsuccessfull Prof Henry is willing to advance his quota
 from the funds of the Smithsonian Institution.

When described in questionnaire is well as I wish or unsuccessfull
 from each individually of the Bureau

If this endeavor meets your approbation it might be
 well to bring the subject before the ~~Smithson~~ Academy
 of Sciences of Phil^a as that body might aid materially
 in the shape of a memorial to Congress, letters addrest
 to the Secy of the Interior Com^r Genl Land Office or
 by letters to members of Congress from your State &c

Some time ago I sent in estimates to the Genl Land
 office for the expenses of illustrations and analysis, & my
 report. And if a movement is made before the Annual
 estimates are sent in to Congress from the Dept. it will
 only be necessary to add say \$1000.00 to the amount
 called for by me to accomplish the object in view.

The funds of the Government are so low that it is very hard
 to obtain an appropriation for any purpose except the
 current expenses of the Dept. & Congress. And therefore it seems
 success one might leave one stone unturned. A memorial
 from your Society or the private letters alluded to might at
 this time have a very important influence in securing an
 appropriation for the expenses of my report, in which several

reminding him that Congress had not yet passed a resolution to cover the expenses for the publication of his report, he pointed out that

if a movement is made before the Annual estimates are sent in to Congress from the Depts. it will only be necessary to add say \$1000.00 to the amount called for by me to accomplish the object in view [i.e., retrieve the meteorite].⁹⁶

Evans hoped that his story about the meteorite would prove so intriguing that Congress would make a modest appropriation for its retrieval. Then, by linking together this expense with that necessary for the publication of his final report, Evans hoped that the publication expenses could be sloughed off as a current rather than past expense. I propose that this was Evans' real goal, and the reason behind his elaborate hoax. He saw this as the only possible route to the recovery of his enormous \$11,074 personal debt. Moreover, Evans had gone out on a limb regarding the money owed his assistants, publicly saying he felt "bound in honor" to pay them out of his own pocket if the Government failed to furnish the funds.⁹⁷ Therefore, it is not difficult to understand why he so strongly felt that he "must leave no stone unturned"⁹⁸ in his efforts to interest Congress in his plan to retrieve the meteorite.

But if Evans' plan succeeded, and Congress made the appropriation, how could the hoax be carried off? As there was no 10-ton meteorite on Bald Mountain, there was obviously nothing for Evans to retrieve. It would not do to claim he couldn't locate it, for he had asserted in his 1 May 1860 letter to Jackson that "there cannot be the least difficulty in my finding the meteorite." Some other reason would have to be found.

Evans' letter to Leidy reveals that he had thought of possible solutions to this problem. His original idea of retrieving the entire meteorite might be "not practicable," he warned:

The object in view is, if possible, is [sic] to enable me to secure the whole meteor, and if that is not practicable to secure large specimens for the different Scientific Societies in the U.S. and Europe and to dig around and under the meteor and make accurate drawings and measurements of the same.⁹⁹

But conceivably Evans could return with only these measurements and drawings, claiming that even the attempt to secure large pieces had proved to be "not practicable."

Evans claimed to Leidy that Henry was willing to financially support such a scheme:

The plan is to make every possible effort to induce Congress to make the necessary appropriation; and if this should prove unsuccessful Professor Henry is willing to advance his quota from the funds of the Smithsonian Institution.¹⁰⁰

But the available evidence does not support this claim. In a letter to Nevil Story-Maskelyne, Keeper of Minerals at the British Museum (Natural History), Henry explained that he was not in favor of urging the government to appropriate funds to retrieve the entire meteorite: "I concluded that the advantage to science would by no means compensate the expense of the enterprise."¹⁰¹ Rather, he advised that the meteorite be dug up, accurately measured and photographed so that an exact plaster copy could be made, "and that specimens be procured which

might be presented to the principal museums of the world." Although he concluded that "I think it probable that these suggestions will in time be acted upon," he did not offer Smithsonian funds to accomplish this end. Nevertheless, Henry's letter does indicate that he was, in fact, interested in receiving a specimen of the Port Orford meteorite for the Smithsonian collections.

But Evans had also hit on another, and possibly better, solution to his problem. Although he had stressed how visible the meteorite was, because it was on a grassy slope that was bare of timber and devoid of rocks in its immediate vicinity, his letter raised the possibility that it might, in fact, no longer be visible. The reason for this suggested itself to Evans in a totally different context. In an agricultural report he wrote to the General Land Office in November, 1859, he described how the soil in the mountainous areas near the coast and between the Cascade and Bitter Root Mountains was enriched by "the vegetable matter brought down by the abundant rains and the melting of snow in the spring."¹⁰² Writing to Leidy only four days later, Evans cleverly turned this around to suit his own purpose. Now, instead of enriching the soil, "the annual accumulation of vegetable matter brought down by melting snows and rain storms would tend materially to cover it [the meteorite] up."¹⁰³ Hence, by the time he returned to Oregon, the meteorite might be entirely covered up, and therefore impossible to relocate. Thus armed, Evans must have felt that if Congress made the appropriation, he was prepared. But Congress repeatedly failed to make the necessary appropriation.

In June 1860, Evans sought and obtained appointment as geologist accompanying a naval expedition to Chiriqui, on the Isthmus of Panama, to ascertain the extent and value of coal deposits there and the practicability of constructing a railroad connecting the Atlantic and Pacific oceans. Evans' motivation, however, was not to advance the cause of science or commerce, but to advance his own cause: "This expedition will aid me much in that body [the House of Representatives] by securing the votes of the Administration Members who on several occasions ... voted against" the supplemental appropriation bill.¹⁰⁴ But this tactic, like the meteorite hoax itself, did not get a chance to succeed, for a few months after his return from Chiriqui, Evans died in April 1861.

With Evans' death and the almost concurrent outbreak of the Civil War, Congress turned its attention to far more pressing matters. The *Geological Survey of Oregon and Washington Territories*, which had been in the hands of the Public Printer at the time of Evans' death, somehow fell out of sight, and became irretrievably lost.¹⁰⁵ Thus, the story of the Port Orford meteorite became an intriguing enigma, eluding all who attempted to solve the mystery of its disappearance.

Identity of the Port Orford Specimen

One of the most puzzling pieces in this story is the Port Orford specimen itself. Unquestionably a genuine meteorite,

where did it really come from? And how did Evans acquire it? Only three pallasites had been discovered in Evans' day: Krasnojarsk (Siberia, 1749), Brahın (Belorussiya, 1810), and Imilac (Chile, 1820–1822).¹⁰⁶ I do not include Anderson (United States, prehistoric) because it was not found until 1882. The Anderson specimen, which was found in the Turner Mounds in Little Miami Valley, Ohio, is actually a transported piece of Brenham (Kiowa County, Kansas). Gran Chaco (Argentina, 1811) is not included because it now is considered to be an Imilac specimen. It just happened that a transported piece from the Imilac shower was the first specimen of that meteorite to be found. Of the three contemporary pallasites, only two had specimens that were widely distributed, and hence could have been accessible to Evans: Krasnojarsk and Imilac.

It is my contention that the Port Orford fragment is a piece of Imilac, and that Evans acquired it in the fall of 1858 while crossing the Isthmus of Panama on his final return trip from Oregon. Henderson suggested to me that the Port Orford specimen might have originated from South America, and that Evans could have picked it up there en route to or from Oregon.¹⁰⁷ But there is no evidence that Evans had ever been in South America. Nor would there have been any need for him to have been; he quite simply could have acquired his specimen while crossing the Isthmus of Panama.

Evans' dramatic change of mood at precisely that time, his assertion that matters in other respects now looked more favorable, and his acknowledgment that he had added "interesting" specimens to his geological collection, suggest that he acquired the meteorite between the time he left Oregon and the time he returned to Washington, D.C. It would have been possible, of course, for him to have acquired it in San Francisco, in any of the ports of call on either the west or east coast, or in Washington, D.C. But it is probable that most Imilac specimens passed through the Panama area on their way to various museums and collectors in North America and Europe.

The major trading post for South American goods in the nineteenth and early twentieth centuries was at the Isthmus of Panama, the quickest and safest seafaring route to Europe and North America. Sugar, fruit, minerals, cloth, and dozens of other products passed through the Isthmus on their way to market.¹⁰⁸

For this reason, it is much more likely that Evans acquired his curio-size specimen there rather than anywhere else.

The Imilac meteorite was discovered sometime around 1820–1822 by two Indians hunting guanacos in the Atacama Desert in Chile (Figure 1-7). At first mistaken for silver, it soon was recognized to be a meteorite, and a specimen was sent to the British Museum in 1827.¹⁰⁹ In his comprehensive *Handbook of Iron Meteorites*, Vagn F. Buchwald alludes to the fact that

in the second quarter of the nineteenth century many of the [meteorite's] fragments were carried in small portions by Indians to Peruvian, Bolivian, Chilean, and Argentinean coast towns from where they were slowly spread to a surprisingly large number of public museums and private collectors.¹¹⁰

Within only a few years of its discovery, fragments had found their way to at least twenty museums and a similar number of private collectors.¹¹¹

Even after this widespread distribution, thousands of fragments still remained at the site. In 1854, R.A. Philippi, who had been commissioned by the Chilean government to investigate the botany and geology of the Atacama Desert, happened to meet one of the original finders of the meteorite, who guided him to the location of the strewnfield. Within a few hours he and his party collected about 1500 fragments, and estimated that an equal amount probably remained there unseen.¹¹² In fact, because of its extremely fragmentary character, Imilac "is no doubt the most commonly represented pallasite in collections."¹¹³

Any attempt to positively pair the Port Orford specimen with an Imilac specimen is fraught with difficulties. My conclusion, reached from a study of the available literature, is based on comparisons of the overall physical appearance, degree of weathering, and detailed chemical composition of the two meteorites. Henderson described the Port Orford as "a sponge like piece of iron with bright, fresh olivine attached to the skeleton structure of iron," containing depressions in which the olivine crystals were no longer present.¹¹⁴ Buchwald, who visited the Imilac site in 1973, mapped the strewnfield, and collected some 2430 small fragments, described a large portion of them as "irregular spongy metal skeletons." Although the olivine crystals were mostly lost from his samples, those that were present were quite fresh, exhibiting a yellowish white to greenish yellow color.¹¹⁵ Moreover, the form of the olivine crystals in the two pallasites is virtually indistinguishable.¹¹⁶

Both the Port Orford and some Imilac fragments exhibit extremely little weathering. The Port Orford's fresh black fusion crust led Henderson to conclude that it must be a relatively recent fall.¹¹⁷ In contrast to ultramoist western Oregon, the Atacama Desert is extremely arid, averaging under 5 mm precipitation annually. Indeed, Buchwald described the area as "belong[ing] to the most arid in the world. ... It is remarkable that samples collected in 1973 look almost exactly like samples recovered about 1823, 150 years ago."¹¹⁸ Although none of the specimens that Buchwald examined exhibited fusion crust, he nevertheless believed that "many ... have lost only little by corrosion." This view undoubtedly reflected the understanding of the situation in the mid-1970s.¹¹⁹ Moreover, Philippi described the surfaces of the small specimens he found in 1854 as "very black."¹²⁰ And the Smithsonian "received a recently found Imilac specimen a little over 10 years ago that has well preserved fusion crust as is observed on the Port Orford specimen."¹²¹ This specimen provided the first concrete evidence that some Imilac specimens are fusion crusted. It is also worth noting that the main portion of the Ilimaes mass, in the mineral collection of the School of Mines, Copiapó, Chile, also is covered by a thick black fusion crust.¹²² The relevance of this meteorite will be discussed below.

The most comprehensive chemical analysis of pallasites was

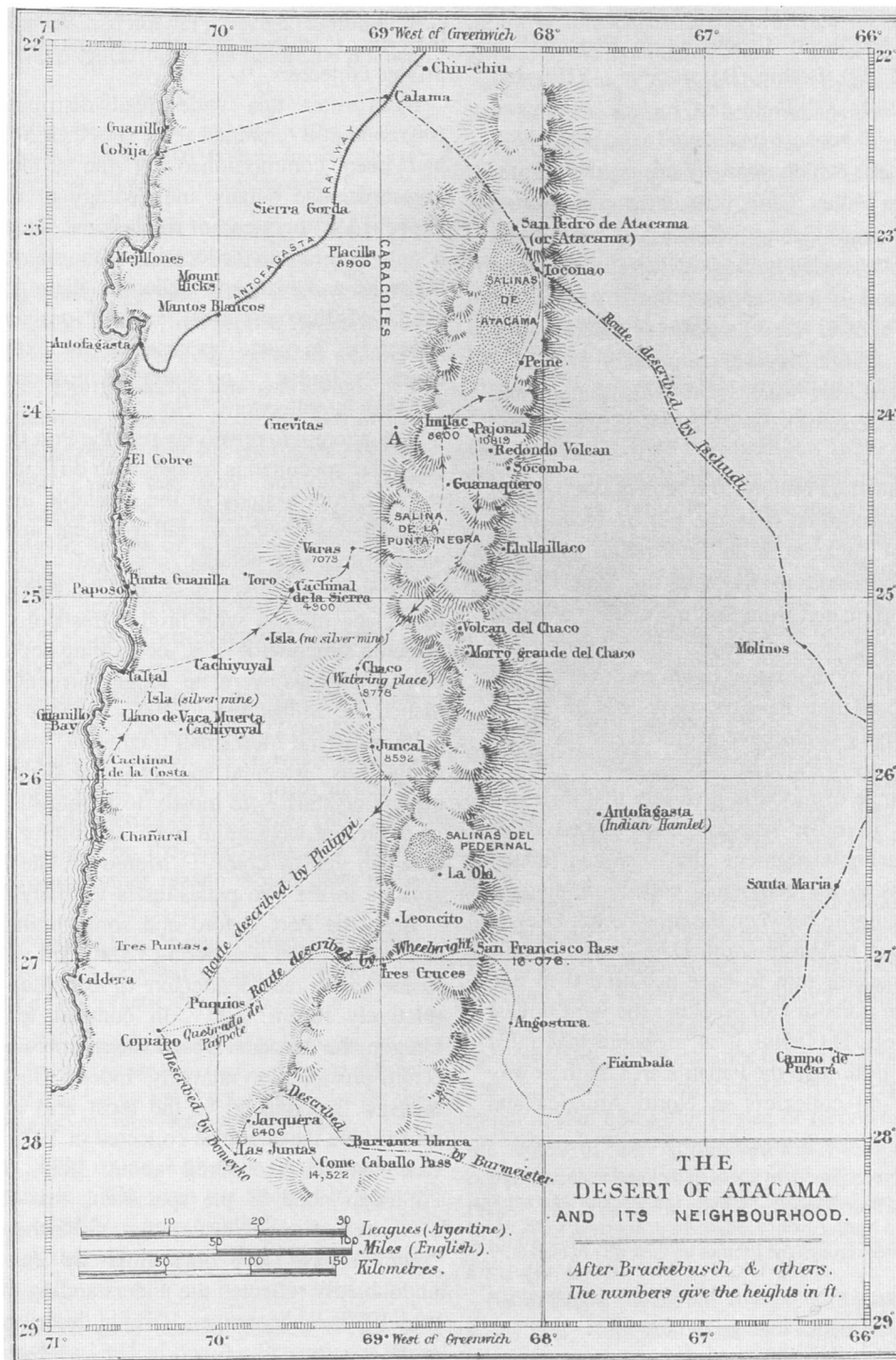


FIGURE 1-7.—The map of the Atacama Desert, Chile, which accompanied L. Fletcher's article "On the Meteorites which Have Been Found in the Desert of Atacama and its Neighbourhood." Imilac, some 120 miles east of Antofagasta, is clearly marked on the route described by R.A. Philippi. Although Ilimaes is not marked on this map, the meteorite bearing this name was found somewhere in the region between Chañaral and Juncal, about 170 miles south of Imilac. From *The Mineralogical Magazine and Journal of the Mineralogical Society*, October 1889.

conducted by Andrew Davis, who undertook a systematic study of trace element abundances for his 1977 doctoral dissertation at Yale University. Some of his pertinent data for the Port Orford, Imilac, and Ilimaes meteorites is summarized in Table 1-1.¹²³ The comparison between Port Orford and Imilac shows that the Ga and the Ir contents of the two meteorites are quite similar, but that Port Orford has a somewhat higher Ni and a lower Ge content than Imilac.

The crucial question, of course, is how significant are these differences? One way to assess this is to compare these differences against those between Imilac and Ilimaes.¹²⁴ Ilimaes is a pallasite that also was found in the Atacama Desert in Chile, about 50 years after Imilac was found, and about 170 miles to the south (Figure 1-7). Meteoriticists consider them a true pair, i.e., as being part of the same fall. Although Imilac and Ilimaes were listed as independent entities in the British Museum (Natural History) *Catalogue of Meteorites* 3rd edition, they were listed as a pair in the 4th.¹²⁵ This comparison shows a very close agreement in the Ga content and only a small difference in the Ni content of the meteorites, but a somewhat larger difference in the Ge and a very large difference in the Ir contents.

As early as 1889, L. Fletcher, Keeper of Minerals in the British Museum (Natural History), pointed out that the name Ilimaes, which is neither Indian nor Spanish, could not be found on any maps, and speculated that "it is far from impossible that the name is a mere misspelling of Imilac, which is itself another version ... of Imilac."¹²⁶ Buchwald agreed with this. His comparisons of the two meteorites convinced him that "since the two pallasites are similar in all essential respects ... the Ilimaes mass must be a transported [piece of Imilac] mass."¹²⁷ In fact, more than a dozen pallasites, all found within a 200-mile radius of Imilac, are regarded by Buchwald as being transported pieces of Imilac.¹²⁸ These pairings help explain the mystery of how there could be so many apparently different falls of a very rare type of meteorite in such a relatively small area. Furthermore, it is worth noting that these falls were not found at random places in the Atacama Desert, but along well-established desert trails:

Nearly all the Atacama masses of known locality have been found on or near the desert tracks; in a certain measure this is due to the country having been there most easily explored, but in some cases it is doubtless a result either of loss during transport or of rejection of the specimens after discovery that they contained no silver.¹²⁹

This lends further support to Buchwald's contention, which has been accepted by nearly all meteoriticists.¹³⁰ Davis, however, has interpreted his data to indicate that the various Atacama pallasites are in fact independent falls.¹³¹

On the whole, the differences in chemical composition between the Imilac and Ilimaes meteorites are of strikingly similar magnitude to the differences between Port Orford and Ilimaes. In fact, with the exception of the large difference in its

TABLE 1-1.—Selected chemical compositions for Port Orford, Imilac, and Ilimaes metal in order of decreasing percent Ni content. Data from Davis, 1977, doctoral dissertation, Yale University.

Pallasite	Ni %	Ga ppm	Ge ppm	Ir ppb
Port Orford	11.3	21.2	34.1	82.1
Ilimaes	10.4	22.4	39.9	112.0
Imilac	9.6	23.1	48.3	80.9

Ir content, Ilimaes falls almost perfectly midway between Port Orford and Imilac (Table 1-1).

Does this mean that if Imilac and Ilimaes are considered a true pair, so too can Port Orford and Ilimaes, and by extension, Port Orford and Imilac? In considering this, it should be kept in mind that some variations are to be expected in as large a body as the parent Imilac meteorite. It is well known, for example, that whereas most specimens of Brenham are typical pallasites, some show large patches of pure nickel-iron, more representative of the iron meteorites.¹³²

At the present time, there cannot be a definitive positive pairing. As the Smithsonian's Roy S. Clarke, Jr., points out:

Unfortunately, there is no easy way to be certain whether the two specimens [Port Orford and Imilac] are from the same or from different falls. Many pallasites have very similar properties. There are several papers that suggest on the basis of chemical data that the two are not from the same fall, but I am not convinced that this work is necessarily conclusive.¹³³

I am, nevertheless, satisfied that on the basis of comparisons of physical appearance, degree of weathering, and chemical composition of the two meteorites, there is sufficient support for my contention that the Port Orford specimen acquired by Evans is, in fact, a piece of Imilac.

Conclusion

John Evans was a happy and carefree explorer in the early days of his field work. During his second trip to Oregon in 1853, for example, he playfully wrote his wife:

I am the most unlucky fellow in the world! The Indians will not scalp me, not even see me; the grizzly bears run away at my approach; the contrary mule, even, will not throw me over his head, and break my neck; I cannot get lost and wander for weeks in the Mountains; the rivers will not drown me & I have had no opportunity to describe a prairie fire! Poor miserable dog—not an adventure to relate!¹³⁴

During these early adventurous exploring trips, Evans did a good job of spying out the land, finding new mountain passes and charting river courses, describing the natural resources, and acquainting others with the vast and complex western terrain. The fossil and mineralogical samples he collected on these trips and sent to specialists for analysis provided at least a beginning for a natural history survey of the Pacific Northwest. But Evans himself had no formal training in the disciplines he served, and

his knowledge of these fields was cursory at best. Perhaps this can help explain both the disappointing nature of his field work and his unprofessional scientific behavior.

It is clear that his severe financial difficulties and his long, frustrating battle with Congress weighed heavily on him, and took their toll. Increasingly, he found that “the cares and perplexities of business before Congress ... occupied almost every moment” of his time. Moreover, he found “the slavery of being obliged to bend to insolent officials” intolerable.¹³⁵ As a result, his outlook changed, leading him to confess that “much of the fire of youthful hope has been lost in the bitter waters of experience.”¹³⁶ His acquisition of a small piece of meteorite in 1858 must have seemed, literally, a heaven-sent way out of his difficulties. It is my contention that in a clever scheme, he used it in a last-ditch attempt to extricate himself from his desperate situation.

I believe Evans chose Oregon as the site of his alleged find for two reasons. In the first place, the idea of mounting a new expedition there to retrieve the meteorite was the key to his scheme to get Congress to pass an appropriation that would wipe out his enormous personal debt. And secondly, he wished to go there, at Congress’ expense, to check on his real estate holdings. Specifically, he chose Bald Mountain because that was the most memorable part of his trip. Not only was it the highest point on his route from Port Orford across the Rogue River Mountains, but the view from its summit was unforgettably spectacular. Nearly a week after crossing its summit, he had occasion to recall the scene from there:

If the traveller will notice the valley of the Umpqua from some high summit in the Calapooya Mountains he will form a pretty good idea of a scene we witnessed from Bald Mountains [sic] ... a valley of mountains covered with timber, occasionally a peak rising sharp and angular against the sky in bold outline. Around this valley of mountains is a higher range of singular grandure; here and there dotted over the lesser elevations are small mountain prairies covered with luxuriant grass, and in some intervening glens lovely little prairies of rich mellow soil. ...¹³⁷

The memory of this beautiful scene remained firmly implanted in his mind years later. Moreover, as his “Descriptive Catalogue of Geological Specimens” shows, he had made collections of rock samples there, so his story would make sense logically (Figure 1-4).

My reconstruction of Evans’ hoax explains all of the puzzles connected with the story of the lost Port Orford meteorite, especially why no mention of its discovery was made in Evans’ journal or his “Descriptive Catalogue,” and why it has not been possible to relocate the meteorite. Evans’ unfamiliarity with meteorites undoubtedly accounted for his inability to realize how difficult it would have been to either hammer a piece off the Port Orford meteorite or to cut it up into several pieces, as he at one point had suggested. This unfamiliarity could also account for his claim for the meteorite’s inordinately large size. The indications that he acquired it in 1858, and not in 1856, as he maintained, explain what otherwise would have been a mysterious three-year delay between the time of its discovery

and that of its analysis by Jackson. And if Evans’ specimen is a piece of Imilac, as I contend, this would explain its fusion crust and fresh appearance. Finally, if indeed he had acquired the specimen on the Isthmus of Panama, as I believe, this might have constituted another reason why he wished to return there in 1860.

It seems highly unlikely that Evans, had he not died in 1861, would have succeeded in his attempt to have the government appropriate funds to retrieve the meteorite in order to place it in the Smithsonian Institution. Only a month before Evans’ death, Henry estimated that it would cost \$20,000 to transport the meteorite.¹³⁸ Neither Evans, Jackson, Henry, nor anyone else could have persuaded Congress to fund such a large amount, especially at a time when civil war seemed imminent. Evans’ hoax, conceived in desperation and brilliant in execution, was doomed by the events of his day. The firing on Fort Sumter sounded its death knell, as it happened to sound Evans’ the following day.

Notes

¹Charles T. Jackson, in the minutes of a meeting, *Proceedings of the Boston Society of Natural History*, 7(1861), page 161.

²W.K. Haidinger, “Einige neuere Nachrichten über Meteoriten, namentlich die von Bokkeveld, New-Concord, Trenzano, die Meteoreisen von Nebraska, von Brazos, von Oregon,” *Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftliche Klasse Sitzungsberichte*, 41(1860), pages 568–572.

³For more on pallasites, especially on their early history, see further Vagn F. Buchwald and Roy S. Clarke, Jr., “A Mystery Solved: The Port Orford Meteorite is an Imilac Specimen.” In Roy S. Clarke, Jr., editor, “The Port Orford, Oregon, Meteorite Mystery,” *Smithsonian Contributions to the Earth Sciences*, 31, pages 25–43.

⁴John Evans to Jackson, 1 May 1860. Quoted in Charles T. Jackson, “A Sketch of the Life and Scientific Services of John Evans, M.D., U.S. Geologist for Oregon and Washington Territories, and the U.S. Chiriqui Exploring Expedition,” *American Journal of Science*, 2nd series, 32(1861), page 313.

⁵Ibid.

⁶The “Memorial to Congress from the Academy of Sciences, Philadelphia” is reprinted in “Report to Accompany Bill S. 149,” 36th Congress, 1st Session, S. Rept. 177, page 19. Serial 1039.

⁷Jackson, “Sketch,” page 315.

⁸Ibid, page 317.

⁹Richard X. Evans, “Dr. John Evans, U.S. Geologist, 1851–1861,” *The Washington Historical Quarterly*, 26(1935), page 89.

¹⁰The journal is in the John Evans Papers, Record Unit 7198, Smithsonian Institution Archives, Washington, D.C.

¹¹W.F. Foshag to George P. Merrill, Head Curator, Department of Geology, Smithsonian Institution, 16 July 1929, George P. Merrill Collection, Record Unit 7177, Box 17, Smithsonian Institution Archives, Washington, D.C. This collection will hereafter be referred to as Merrill Collection. I thank Roy S. Clarke, Jr., for calling my attention to this letter. See further Buchwald and Clarke, “A Mystery Solved.”

¹²J.H. Pruett, “Treasure for the Finding: Oregon’s Lost Meteor [sic],” *The Sunday Oregonian*, 21 November 1937, page 9.

¹³See E.P. Henderson to Alexander Wetmore, Assistant Secretary of the Smithsonian Institution, 10 and 17 June 1939, Registrar, 1834–1958, Accession Records, Record Unit 305, Accession no. 151638, Smithsonian Institution Archives, Washington, D.C.

¹⁴Hollis M. Dole to George J. Hohnstein, 25 November 1964. I am indebted

to Richard Pugh for providing me with copies of this and other letters from the late Erwin F. Lange's file on the Port Orford meteorite. This file will hereafter be referred to as Lange File.

¹⁵E.P. Henderson and Hollis M. Dole, "The Port Orford Meteorite," *The Ore Bin*, 26(1964), page 120.

¹⁶Ibid.

¹⁷Evans to Joseph S. Wilson, Commissioner of the General Land Office, 24 August 1860, Records of the General Land Office, Record Group 49, National Archives, Washington, D.C. These records will hereafter be referred to as RG 49.

¹⁸Ellen C. Sedell, "The Lost Port Orford Meteorite," *Oregon Historical Quarterly*, 69(1968), page 37.

¹⁹Ibid, page 32.

²⁰The Smithsonian houses the main mass of the Port Orford meteorite (Accession no. 64916). Originally weighing 25 g, small amounts of material have been removed from it for study, and its current weight is now 17.7 g. The only other specimens of this meteorite are in the Naturhistorisches Museum Wien in Vienna (3.5 g), the Arizona State University's Collection of Meteorites in Tempe (0.9 g), The Natural History Museum, London (0.5 g), and the India Geological Survey's Collection in Calcutta (0.2 g). For more on these specimens, see further Buchwald and Clarke, "A Mystery Solved."

²¹Henderson and Dole, "The Port Orford Meteorite," page 116.

²²Henderson to George J. Hohnstein, 1 December 1964, Lange File.

²³Dole to Henderson, 4 December 1964, Lange File.

²⁴Sedell, "The Lost Port Orford Meteorite," pages 33, 36.

²⁵Erwin F. Lange, "Dr. John Evans, U.S. Geologist to the Oregon and Washington Territories," *Proceedings of the American Philosophical Society*, 103(1959), page 484.

²⁶Roy S. Clarke, Jr., personal communication to the author, 8 December 1986.

²⁷Evans' "Descriptive Catalogue of Geological Specimens Collected in Oregon and Washington Territory" is in Record Unit 305, Box 5 for 1857, Smithsonian Institution Archives, Washington, D.C.

²⁸Jackson, "Sketch," page 315, note.

²⁹Brian Mason, "The Pallasites," *American Museum Novitates*, 2163(1963), page 2, table 1.

³⁰Vagn F. Buchwald, *Handbook of Iron Meteorites, Their History, Distribution, Composition and Structure* (Berkeley, 1975), volume 1, page 38, table 20.

³¹Ibid, page 35, table 18. See also Ellis Peck, "The Fate of a Kansas Meteorite Crater," *Sky and Telescope*, 58(1979), page 128. I thank Douglas Borgard for calling my attention to this article.

³²A.L. Graham et al., *Catalogue of Meteorites, with Special Reference to Those Represented in the Collection of the British Museum (Natural History)*, 4th edition (London, 1985), page 171.

³³Evans to Joseph Leidy, 25 November 1859, Joseph Leidy Papers, Academy of Natural Sciences, Philadelphia, Pennsylvania. These papers will hereafter be referred to as Leidy Papers.

³⁴Jackson, "Sketch," page 313.

³⁵The fact that Bald Mountain was the highest point on Evans' journey is mentioned in his "Descriptive Catalogue," page 15.

³⁶Quoted in Jackson, "Sketch," page 314.

³⁷Evans to Jackson, 1 May 1860. Quoted in Jackson, "Sketch," pages 313, 314. For a convincing discussion of why the river mentioned cannot be the Sixes River, see Lincoln LaPaz, "Contribution 5: The Evans Meteorite." In Lincoln LaPaz, editor, "Topics in Meteoritics: Their Recovery, Use, and Abuse from Paleolithic to Present." *University of New Mexico Publications in Meteoritics*, number 6 (Albuquerque, 1969), pages 113, 114. LaPaz was the Director of the Institute of Meteoritics at the University of New Mexico.

³⁸Ibid.

³⁹Lewis A. McArthur, *Oregon Geographic Names*, 3rd edition (Portland, Oregon, 1965), page 30, entry for "Bald Mountain."

⁴⁰The journal quotations are from Evans' "Route from Port Orford Across the Rogue River Mountains."

⁴¹McArthur, page 329, entry for "Johnson Mountain." For an extensive account of the early mines worked there, see J.S. Diller, *Geologic Atlas of the United States, Port Orford Folio, Oregon* (Washington, D.C., 1903), pages 5, 6.

⁴²Foshag to George P. Merrill, 4 July 1929, Merrill Collection. I thank Roy S. Clarke, Jr., for calling my attention to this letter.

⁴³See further S. Breiner, *Applications Manual for Portable Magnetometers* (Sunnyvale, California, 1973), page 3.

⁴⁴Ibid, page 43, figure 46.

⁴⁵The old trails are delineated in Diller, *Port Orford Folio*, "Topographic Sheet." They are also discussed and shown in the notes and plats accompanying the 1876 and 1910 Bureau of Land Management surveys of the area (T.32S., R.12W.).

⁴⁶For more on this mine, see Len Ramp, "Chromite in Southwestern Oregon." *State of Oregon, Department of Geology and Mineral Industries, Bulletin Number 52* (Portland, 1961), page 112.

⁴⁷See further H.E. Hawkes, "Magnetic Exploration for Chromite." *Geological Survey Bulletin 973-A* (Washington, D.C., 1951), pages 1-3.

⁴⁸Douglas Borgard, personal conversation with the author.

⁴⁹This fear was voiced in Evans' letter to Joseph Leidy, 25 November 1859, Leidy Papers.

⁵⁰Details of Evans' early life are from Jackson, "Sketch"; Lange, "Dr. John Evans"; and Richard X. Evans, "Dr. John Evans."

⁵¹A. Litton to Evans, 12 March 1854, Richard X. Evans Collection, Special Collections Division, Georgetown University Library, Washington, D.C.

⁵²George P. Merrill, "Contributions to the History of American Geology." *Annual Report of the Smithsonian Institution, United States National Museum, 1904* (Washington, D.C., 1906), page 413.

⁵³Ibid., page 585.

⁵⁴I. Stevens to Evans, 11 April 1853, "Pacific Railroad Survey," Isaac Ingalls Stevens Papers, Box 5, Folder 30, University of Washington Library, Seattle, Washington. These papers will hereafter be referred to as Stevens Papers.

⁵⁵Stevens to Evans, 22 April 1853, Stevens Papers, Box 5, Folder 30.

⁵⁶William H. Goetzmann, *Exploration and Empire, The Explorer and the Scientist in the Winning of the American West* (New York, 1960), page 491. For more on this affair, see F.V. Hayden to James Hall, 16 May 1853 and F.B. Meek to James Hall, 19 May 1853. Quoted in George P. Merrill, *The First One Hundred Years of American Geology* (New York, 1964), pages 697-699. Hall, a geologist at the Rensselaer Polytechnic Institute, was a prominent New York State geologist and paleontologist.

⁵⁷Meek to James Hall, 7 June 1853. Quoted in Merrill, *First One Hundred Years*, page 706.

⁵⁸Ibid.

⁵⁹J. Leidy to F.V. Hayden, 18 July 1855. Quoted in Nathan Reingold, *Science in Nineteenth-Century America, a Documentary History*, (New York, 1964), page 176.

⁶⁰I. Stevens, "Report of Explorations for a Route for the Pacific Railroad Near the Forty-seventh and Forty-ninth Parallels of North Latitude, from St. Paul to Puget Sound," in 33rd Congress, 2nd Session, *House Executive Document 91*, volume 1, pages 230, 282. Serial 791.

⁶¹Evans to A.A. Humphreys, Corps of Topographical Engineers, 14 February 1855, Records of the Office of Explorations and Surveys, Record Group 48, National Archives, Washington, D.C. These records will hereafter be referred to as RG 48. Humphreys was in charge of the Pacific Railroad Survey Office.

⁶²Stevens to Evans, 11 April 1853, Stevens Papers, Box 5, Folder 30.

⁶³Evans' "Directions for the Mineralogical and Geological Examinations" are in Stevens, "Report of Explorations," pages 12, 13.

⁶⁴Evans to Thomas A. Hendricks, Commissioner of the General Land Office, 16 February 1857, RG 49.

⁶⁵Ibid.

⁶⁶Merrill, *First One Hundred Years*, page 319.

⁶⁷J. Butterfield to Evans, March 1851, RG 49.

⁶⁸Evans to Butterfield, 8 March 1851, RG 49.

- ⁶⁹Butterfield to Evans, March 1851, RG 49.
- ⁷⁰Evans to Butterfield, July 1851, RG 49.
- ⁷¹Evans to Butterfield, 4 August 1852, RG 49.
- ⁷²"Memorandum of the Results of the Geological Survey of Oregon and Washington Territories, and the Circumstances Attending its Institution and Progress, from Official Sources," in "Report to Accompany Bill S. 149," page 17.
- ⁷³Evans to Hendricks, 16 February 1857, RG 49.
- ⁷⁴"Memorandum," page 18.
- ⁷⁵Evans, "Memorandum, General Results of the Geological Survey of Oregon and Washington Territories" [November 1857], RG 49.
- ⁷⁶Evans to Hendricks, 24 October 1857, RG 49.
- ⁷⁷"Extract from the Annual Report of the Commissioner of the General Land Office to the Secretary of the Interior, dated November 30, 1857," in "Memorandum," page 7.
- ⁷⁸See Erwin F. Lange to Paul C. Musselman, 9 October 1964, Lange Papers; a copy of a deed of sale dated 3 September 1856, *ibid*; and Evans to F.B. Meek, 19 February 1858, Fielding B. Meek Papers, Record Unit 7062, Box 2, Folder 14, Smithsonian Institution Archives, Washington, D.C. These papers will hereafter be referred to as Meek Papers. Musselman, an osteopath from Stella, Missouri, unearthed many previously unknown documents in his attempt to solve the Port Orford meteorite mystery.
- ⁷⁹Evans to Hendricks, 16 February 1857, RG 49.
- ⁸⁰Evans to Meek, 19 February 1858, Meek Papers, Box 2, Folder 14.
- ⁸¹Evans to Meek, 22 February 1858, Meek Papers, Box 2, Folder 14.
- ⁸²Evans to Hendricks, 5 May 1858, RG 49.
- ⁸³Evans to Sarah Z. Evans, 3 October 1858, David Bushnell Papers, College of William and Mary, Williamsburg, Virginia. These papers will hereafter be referred to as Bushnell Papers.
- ⁸⁴*Ibid*.
- ⁸⁵Evans to Leidy, 7 December 1858, Leidy Papers.
- ⁸⁶*Ibid*.
- ⁸⁷Evans to Hendricks, 28 November 1856, RG 49.
- ⁸⁸Evans to Hendricks, 26 March 1858, RG 49.
- ⁸⁹Evans to Sarah Z. Evans, 3 October 1858, Bushnell Papers.
- ⁹⁰This is further corroborated in Evans to Jackson, 20 February 1860, Lange Papers.
- ⁹¹Jackson to A.D. Bache, 28 December 1859, Alexander Dallas Bache Papers, Microfilm Edition, Reel number 2, Library of Congress, Washington, D.C. Bache, the Superintendent of the Coast Survey, was one of the greatest American scientific promoters, organizers, and administrators of his generation. For more on meteorite collectors in the nineteenth century, see John G. Burke, *Cosmic Debris, Meteorites in History* (Berkeley, 1986), chapter 6, "Curators and Collectors," pages 174–212.
- ⁹²*Ibid*.
- ⁹³Brian Mason, "Mineral Sciences in the Smithsonian Institution." In George S. Switzer, editor, "Mineral Sciences Investigations, 1972–1973," *Smithsonian Contributions to the Earth Sciences*, 14(1975), page 2; Burke, page 201.
- ⁹⁴Evans to Thomas Stewardson, Corresponding Secretary of the Academy of Natural Sciences of Philadelphia, 4 February 1860, Association of American Geologists and Naturalists Papers, Academy of Natural Sciences, Philadelphia, Pennsylvania.
- ⁹⁵Evans to Leidy, 25 November 1859, Leidy Papers.
- ⁹⁶*Ibid*.
- ⁹⁷Evans to Joseph S. Wilson, 21 November 1859, RG 49.
- ⁹⁸Evans to Leidy, 25 November 1859, Leidy Papers.
- ⁹⁹*Ibid*.
- ¹⁰⁰*Ibid*.
- ¹⁰¹J. Henry to N. Story-Maskelyne, 11 March 1861, Joseph Henry Papers, Smithsonian Institution Archives, Washington, D.C.
- ¹⁰²Evans to S.A. Smith, Commissioner of the General Land Office, 21 November 1859, RG 49.
- ¹⁰³Evans to Leidy, 25 November 1859, Leidy Papers.
- ¹⁰⁴Evans to Jackson, 30 August 1860, Lange Papers.
- ¹⁰⁵For efforts to find this missing *Geological Survey*, see Sedell, "The Lost Port Orford Meteorite," pages 42–45, and LaPaz, *Topics in Meteoritics*, pages 136–138.
- ¹⁰⁶See further Mason, "Pallasites," page 2, table 1, and Buchwald and Clarke, "A Mystery Solved."
- ¹⁰⁷E.P. Henderson, personal conversation with the author, 23 July 1986.
- ¹⁰⁸Tom Miller, *The Panama Hat Trail: A Journey from South America* (New York, 1986), page 15.
- ¹⁰⁹L. Fletcher, "On the Meteorites which Have Been Found in the Desert of Atacama and its Neighbourhood," *The Mineralogical Magazine and Journal of the Mineralogical Society*, 8(1889), page 253.
- ¹¹⁰Buchwald, *Handbook*, volume 3, page 1393.
- ¹¹¹For a listing of these, see Otto Buchner, *Die Meteoriten in Sammlungen* (Leipzig, 1863), page 127.
- ¹¹²Fletcher, "On Meteorites Found in the Desert of Atacama," page 249.
- ¹¹³Buchwald, *Handbook*, volume 3, page 1396.
- ¹¹⁴E.P. Henderson to Lincoln LaPaz, 3 December 1941. Quoted in LaPaz, *Topics in Meteoritics*, page 125.
- ¹¹⁵Buchwald, *Handbook*, volume 3, page 1398.
- ¹¹⁶Carleton B. Moore, personal communication to the author, 24 September 1986. See also Peter R. Buseck, "Pallasite Meteorites: Mineralogy, Petrology and Geochemistry," *Geochimica et Cosmochimica Acta*, 41(1977), page 723, table 1.
- ¹¹⁷Henderson to LaPaz, 3 December 1941.
- ¹¹⁸Buchwald, *Handbook*, volume 3, page 1400.
- ¹¹⁹*Ibid*, page 1398.
- ¹²⁰R.A. Philippi, "Meteoritic Iron of Atacama," *The U.S. Naval Astronomical Expedition to the Southern Hemisphere during the Years 1849–50*, 51, 52 (Washington, D.C., 1855), volume 2, page 288.
- ¹²¹Roy S. Clarke, Jr., personal communication to the author, 8 December 1986.
- ¹²²See Henry A. Ward, "Three New Chilean Meteorites," *Proceedings of the Rochester Academy of Science*, 4(1906), page 226.
- ¹²³Andrew Davis, "The Cosmochemical History of the Pallasites" (doctoral dissertation, Yale University, 1977), pages 77–79.
- ¹²⁴*Ibid*.
- ¹²⁵Compare Max H. Hey, *Catalogue of Meteorites with Special Reference to Those Represented in the Collection of the British Museum (Natural History)*, 3rd edition (London, 1966), page 211, entry for "Ilmaes" with A.L. Graham et al., *Catalogue of Meteorites*, 4th edition (London, 1985), page 174, entries for "Ilmaes" and "Imilac."
- ¹²⁶Fletcher, "On Meteorites Found in the Desert of Atacama," page 260.
- ¹²⁷Buchwald, *Handbook*, volume 3, page 1394.
- ¹²⁸*Ibid*, page 1399.
- ¹²⁹Fletcher, "On Meteorites Found in the Desert of Atacama," page 234.
- ¹³⁰See, e.g., Edward R.D. Scott, "Pallasites: Metal Composition, Classification and Relationships with Iron Meteorites," *Geochimica et Cosmochimica Acta*, 41(1977), page 352 and A.L. Graham et al., *Catalogue of Meteorites*, page 174.
- ¹³¹Davis, "The Cosmochemical History of the Pallasites," pages 269, 270.
- ¹³²Mason, "Pallasites," page 4.
- ¹³³Roy S. Clarke, Jr., personal communication to the author, 8 December 1986. How subsequent studies led Buchwald and Clarke to the conviction that Port Orford and Imilac are indeed from the same fall is the central theme of their paper "A Mystery Solved."
- ¹³⁴Evans to Sarah Z. Evans, 19 October 1853, Bushnell Papers.
- ¹³⁵Evans to Sarah Z. Evans, 26 April 1855, John Evans Papers, Library of Congress, Washington, D.C.
- ¹³⁶Evans to [A.A. Humphreys?], 9 February 1855, RG 48.
- ¹³⁷Evans, "Route from Port Orford Across the Rogue River Mountains," entry for 27 July 1856.
- ¹³⁸Burke, *Cosmic Debris*, page 202.

2. A Mystery Solved: The Port Orford Meteorite is an Imilac Specimen

Vagn F. Buchwald and Roy S. Clarke, Jr.

Introduction

For decades it has been the lot of Smithsonian Institution meteorite curators to receive large numbers of inquiries about the Port Orford meteorite. Does this legendary 10-ton pallasite that John Evans (1812–1861) allegedly found in 1856 high on a mountainside overlooking Oregon's Pacific Coast really exist, and what information can you give me to help me find it? Is it true that the Smithsonian Institution will pay \$2,000,000 for its recovery? These and related questions have been asked of us, of other U.S. Government officials, and of state and local officials for much of this century. Curators, archivists, and librarians in Washington, D.C., have answered hundreds of letters and phone calls, and many visitors have talked with staff members, consulted related documents, and have been shown the Port Orford meteorite specimen. Officials in Oregon have had to cope with hundreds of treasure hunters drawn to the area by fanciful journalistic accounts but ill-prepared for the rigors of meteorite searching in the inaccessible Siskiyou National Forest.

The Port Orford story began to unfold in 1859 at meetings of the Boston Society of Natural History. Chemist Charles T. Jackson (1805–1880) announced receiving for analysis several mineralogical specimens from John Evans, a United States Government contract geologist-explorer of the Northwest. Jackson immediately recognized one small specimen as a pallasite meteorite (Jackson, 1860). Details of the find in the mountains near the coastal settlement of Port Orford, in the Coos Bay region of southwestern Oregon were revealed over several months in exchanges of letters between Evans and Jackson (Jackson, 1861). These reports led to a generally accepted view that Jackson's small meteorite specimen had been removed by Evans from a 10-ton pallasite, and that Evans could easily relocate the mass. Efforts to raise the funds to retrieve it for the Smithsonian Institution were initiated with

surprising speed (Plotkin, 1992; Burke, 1986:202), made good progress for a period, but languished due to Evans' untimely death and the onset of the Civil War. The story was revived in the early part of this century and captured the public's imagination.

The published accounts of some of the more serious writers clearly support Evans' discovery and present him as a well-prepared scientist of impeccable character (Jackson, 1861; Lange,¹ 1959; Sedell, 1968). The small specimen, which Evans used to demonstrate that he had found a large meteoritic mass in the then remote Oregon Territory, came to the Smithsonian meteorite collection from the Boston Society of Natural History in 1920. It is certainly a legitimate meteorite, and there is every reason to believe that it is the same specimen that Evans sent to Jackson.

From the point of view of the Smithsonian curators, however, the discovery story proved hard to live with as it left nagging questions unanswered. Documentation previously accessible to us contained no firsthand account of the actual find, and the fragments of Evans' journal that survive and cover the period during which the meteorite was allegedly discovered do not mention the meteorite. This led to confusion when attempts were made to retrace Evans' route in order to relocate it. It also seemed unreasonable that a well-grounded and experienced scientific explorer of the late 1850s would find such a giant meteorite and not thoroughly document and announce the discovery. A 10-ton pallasite is a truly exotic specimen, both in the sense of being introduced from afar and of being excitingly different. How could such a discovery have escaped being immediately proclaimed?

A brief excursion into Smithsonian records demonstrates the seriousness with which the National Museum of Natural History viewed the story and indicates that efforts were made during a period of limited resources to get at the truth. Curator William F. Foshag made the first Smithsonian attempt to locate the lost 10-ton mass, and his visit to the Siskiyou National Forest was conducted in cooperation with the U.S. Forest Service. In a letter of 4 July 1929 written from Gold Beach, Oregon, Foshag reported to aging Head Curator George P.

Vagn F. Buchwald, Department of Metallurgy, Technical University of Denmark, 2800 Lyngby, Denmark. Roy S. Clarke, Jr., Division of Meteorites, Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560.

Merrill in Washington, D.C.:

I have delayed in writing you in the hope I might have soon good news to impart but since we have now just returned from Iron Mountain I can only report the Evans meteorite is still lost. I feel reasonably sure it is not on Iron Mountain and now feel inclined to believe that Johnson Mountain is the place. Lack of time and funds prevented us from searching this latter place.

From information gathered from old residents and from the lay of the land I believe I can now trace quite accurately the exact trails over which Evans travelled and believe another attempt would have a reasonable chance to succeed [sic].

The country is mountainous and accessible only by pack train. The greatest difficulty is that the old grassy slopes have, under forest protection, been reclaimed by brush and timber. The old trails, however, are still being travelled and I feel reasonably certain that Evans never left the trail for any great distance and still make the daily mileage he reports. I will outline for future reference all information I have gathered in my official report.

We scoured Iron Mountain from one end to the other, going over those slopes that may once have been grassy and free of boulders in great detail.²

Unfortunately, Foshag's official report, which other records extant refer to, is no longer retrievable.

Merrill responded in a letter of 9 July 1929 directed to Foshag in Santa Monica, California:

I am of course sorry you did not find the meteorite, but am not surprised as I do not and never have believed it to be on Iron Mountain. Bald Mountain, north of the Big Bend is the place. The idea of looking for it on Iron Mountain was wholly Mr. Gonyer's and I am disgusted at the result.

But I shall be glad to see you back here. I am very tired of being the whole thing, so please do not delay your coming.³

Merrill died a few weeks later at age 75 on 15 August 1929. The vacancy created was used to hire E.P. Henderson later that year.

Henderson conducted the second Smithsonian search. This time the objective was to determine how accurately Evans' route could be followed using the log of his travels, and also to try to relocate the lost meteorite. Writing from Powers, Oregon, on 10 June 1939 Henderson reported that he had been on the job backpacking for a week and covered a lot of ground, but for the next part of the trip he planned to "outfit a pack train of his own." Writing again from Powers on 17 June, he reported that he had "walked 150 miles over these trails not counting the wild dashes of several hundred feet off the trail when promising rock would be seen."⁴ He commented further that his efforts had failed in locating the meteorite although a thorough search had been made.

At the urging of Hollis M. Dole, State Geologist of Oregon, an account of Henderson's trip was eventually published (Henderson and Dole, 1964). These authors were clearly skeptical of Evans' story, and pointed to problems with Evans' journal and apparent contradictions between the journal and Evans' letters to Jackson. They stressed that the journal was not in Evans' hand, but was a presumed later transcription of field notes by someone else, and that the route from Port Orford across the Rouge River Mountains as described was ambiguous when compared to the actual field situation. They found the presence of fusion crust and the obvious freshness of the Port Orford specimen to be inconsistent with long residence time in

the climate of the area, and claimed that the physical characteristics of the Port Orford specimen demonstrated that it could not have been removed from a larger mass. It also interested them that the 1850s and 1860s had been a time when local residents stimulated by the recent discoveries of gold in California had become prospectors looking for gold and other precious metals. Prospectors had been searching the area before Evans visited it, and they continued to search for years after he died. Would they not have found the giant pallasite if it were as obvious as Evans claimed? The authors produced no hard evidence, however, for doubting Evans' veracity, and as unsuccessful attempts to find the meteorite did not prove that it was not hidden somewhere in the region, there appeared to be little more that could be done by meteorite scientists. The record was incomplete, and if the gaps were to be filled the research skills of an historian seemed to be required.

If we make the reasonable assumption that Jackson's reports were accurate, there appear to be only three possible origins for the pallasite specimen that Jackson received from Evans: (1) the specimen was obtained exactly as Evans claimed, from a previously unknown meteorite in Oregon, (2) the specimen was from a previously unknown meteorite that was somehow obtained by Evans, but not necessarily from a giant mass nor from Oregon, or (3) it was a specimen from a previously known meteorite obtained from a collector or dealer. Choice number one became increasingly difficult to believe as the years went by and the 10-ton mass was not found, and either choices two or three implied something was seriously wrong with Evans' story. Folklore, however, held this to be unlikely.

The specimen itself, of course, is a source of clues. Is it a highly distinctive meteorite, of unusual composition, or one that has been subjected to a terrestrial or preterrestrial history that sets it apart in some way? Is it similar to other known meteorites? Comparatively little modern work has been done on the Port Orford meteorite. It was listed by Mason (1963) in his discussion of the pallasite group of meteorites, described briefly by Henderson and Dole (1964), its olivine composition was given by Buseck and Goldstein (1969), and Buseck (1977) gave petrographic observations. Possible pairings with known meteorites have been considered. As a side issue in broader geochemical studies of pallasite metal, Scott (1977) and Davis (1977) considered it most likely that Port Orford was a previously unknown meteorite. Their work clearly demonstrated that it was a main group pallasite, as are the great majority of pallasites. Minor chemical differences, however, seemed to indicate that it was not paired with the meteorite that was considered the most obvious candidate, the Imilac, Chile, main group pallasite. Prior to our work, no really comprehensive study of the specimen had been undertaken and there seemed to be no good reason for undertaking one. Documentation was suspect, the specimen was very small, and it was apparently a piece of an ordinary pallasite.

The context in which the Port Orford story must be viewed, however, has recently changed abruptly and dramatically.

Howard Plotkin, an historian of science, became fascinated with the Port Orford meteorite story. He first searched the purported Oregon locality in June 1986 and returned the following June hoping that his field work would yield information that would lead to the recovery of the 10-ton meteorite. His first search was followed by a visit to the Smithsonian Institution's meteorite collection in July 1986, where he talked with both E.P. Henderson and collection manager Twyla Thomas. On 26 November 1986 Plotkin wrote Roy S. Clarke, Jr., inquiring into his views on the Port Orford story, and thus began what was to develop into a lively correspondence. As a consequence, Plotkin sent an early draft of his paper reinterpreting Evans' competence, character, and motivations to the Smithsonian in the late summer of 1987 (Plotkin, 1992), shortly before Vagn Buchwald arrived for an extended stay. We were fascinated with Plotkin's surprising evaluation of Evans' motivations, and with his conclusion that Evans had perpetrated a deliberate hoax using the meteorite specimen as bait. Plotkin further concluded that the Port Orford specimen is a piece of the Imilac, Chile, shower.

We found Plotkin's historical arguments persuasive and appealing, and were stimulated to look at the Port Orford specimen anew. Could we adduce technical evidence that would be persuasive in establishing Port Orford as an Imilac individual? Buchwald decided to undertake a thorough metallographic examination of the Port Orford specimen with particular emphasis on a comparison with the Imilac shower. Over the years he had obtained detailed familiarity with the Imilac meteorite as a result of examinations of numerous museum specimens, field work that included defining the Imilac strewnfield and the recovery of many small Imilac specimens, and a thorough knowledge of the older, obscure literature of Imilac and related meteorites (Buchwald, 1975).

Meteorite pairing is a general, long-standing, and occasionally severe problem in meteoritics. An approach to understanding its magnitude may be made by consulting the *Catalogue of Meteorites* for the hundreds of synonyms listed there (Graham et al., 1985). Currently, the pairing problem is particularly acute and receiving much attention from those who are involved in the study of Antarctic meteorites (Scott, 1989). The decision to pair two specimens, that is, assign them to the same meteorite fall, may be as simple as recognizing that they were found close together, are of the same class, and are of the same general state of preservation. Pairing meteorites of unusual or distinctive properties is frequently straightforward. However, pairing becomes a much more complex problem when many meteorites are found to have accumulated over long periods of time in the same general area, such as in Antarctica or Roosevelt County, New Mexico (Marvin, 1989; Huss, 1990; Zolensky et al., 1990).

Individuals among main group pallasites, the class that includes both Port Orford and Imilac, are difficult to distinguish from each other on the basis of mineralogical, structural, and chemical properties. There is close similarity

and overlapping of characteristics within the group, and the ranges of variation within an individual meteorite fall have not been rigorously defined. These considerations are among our reasons for presenting the results of this unusually thorough meteorite pairing study, one that we believe contributes not only to solving the problem at hand but also to the methodology of pairing studies. These comprehensive studies have led us to the belief that the Port Orford specimen is indeed a transported piece of the Imilac meteorite shower, and that Evans' story was fabricated for his own purposes.

ACKNOWLEDGMENTS

Gero Kurat, Natural History Museum, Vienna, Austria, graciously made the Vienna Port Orford specimen available to us for study and provided translation of catalog information. Carleton B. Moore and Charles F. Lewis, The Arizona State University, Tempe, provided the ASU Port Orford specimen for examination.

Howard Plotkin, University of Western Ontario, London, Canada, provided the historical insights that stimulated us to undertake this work, and his cogent comments and generous encouragement have continued throughout its realization. William A. Deiss and William E. Cox provided access to and materials from the Smithsonian Institution Archives.

This paper has benefited from critical reviews by Andrew M. Davis, The Enrico Fermi Institute, The University of Chicago, Chicago, Illinois; Robert T. Dodd, Department of Earth and Space Sciences, State University of New York at Stony Brook, Stony Brook, New York; Ursula B. Marvin, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts; and Marc Rothenberg, Joseph Henry Papers, Smithsonian Institution, Washington, D.C.

This work was initiated while V.F. Buchwald was a visiting scientist in the Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, D.C., September 1987 through January 1988. We are both indebted to the Suzanne Liebers Erickson Fund, and R.S. Clarke, Jr., to the Research Opportunities Fund, Smithsonian Institution, for partial financial support.

Pallasites and Their Early History

Before describing the technical examination of specimens it will be helpful to comment briefly on the pallasite group of meteorites, and the situation that leads to the Imilac, Chile, meteorite being the obvious pairing candidate if Evans' story was fabricated.

Pallasites consist of metal (FeNi) and olivine [(Mg,Fe)₂SiO₄] in roughly equal volumes, with minor amounts of troilite (FeS) and schreibersite [(Fe,Ni)₃P]. The metal forms a three-dimensional framework that encloses cm-size olivine crystals. Figure 2-1 illustrates this relationship on a polished surface of the Salta individual of the Imilac

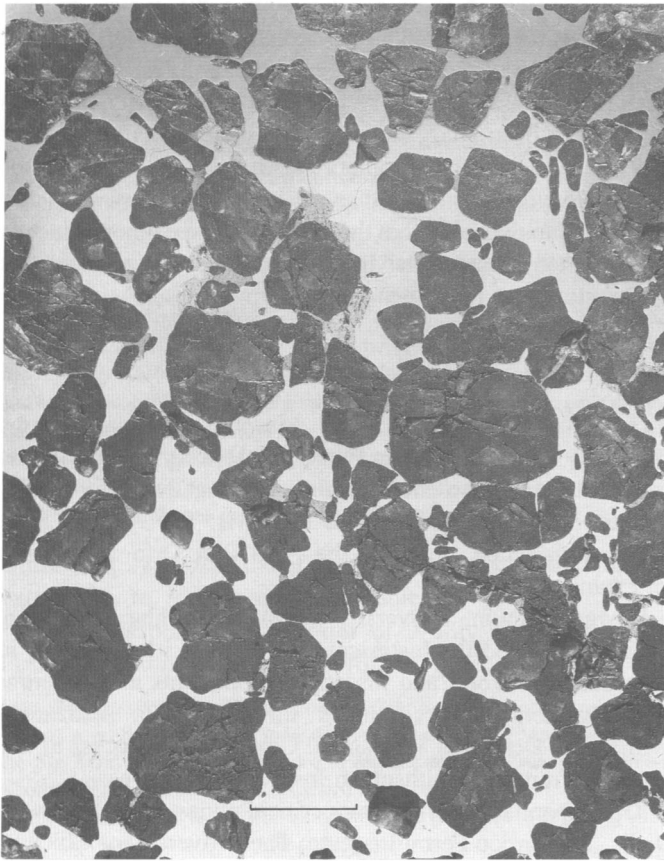


FIGURE 2-1.—Imilac, Chile (USNM#1333), pallasite. A polished surface of the Salta individual from the Imilac shower, emphasizing the relationship between metal and olivine. The dark, cracked, and somewhat angular fragmental material is olivine. The white to gray matrix is unetched metal. The slightly darker gray areas at olivine/metal interfaces are troilite or schreibersite. Scale bar 1 cm.

shower. The metal is complex (Figure 2-2) and consists of several minerals and mineral associations: kamacite (low-Ni FeNi, 5–7.5 wt% Ni), taenite (high-Ni FeNi, 52–35 wt% Ni), tetrataenite (ordered FeNi, 52–48 wt% Ni), plessite (a structural association of taenite, martensite, and kamacite), and chromite (FeCr_2O_4), which frequently contains significant quantities of Mg and Al. Troilite and schreibersite occur at interfaces between metal and olivine, as well as within metal. Olivine is associated with minor amounts of phosphate minerals, as will be discussed below, and very rarely contains P in substitution for some of its Si.

According to recent statistics, 39 different pallasite falls are known, and only one of these falls was actually observed, the Marjalahti fall of 1902 in Karelia, Russia (Graham et al., 1985:227). Pallasites make up 1.4% of the total number of known meteorites, and only 0.1% of the observed falls. Meteorites in all of their variations are rare, and pallasites are a minor component of this rare population. Their theoretical importance derives from the unique association of massive,

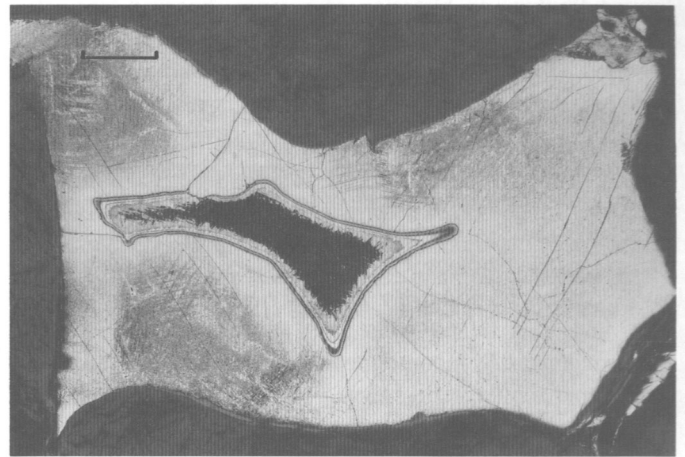


FIGURE 2-2.—Imilac (Copenhagen specimen), polished and etched surface. The metallic regions of pallasites form an almost continuous sponge with olivine crystals (black, along all four edges) in the interstices. At high temperature, the metal was single crystal taenite; upon cooling, kamacite nucleated at metal/olivine interfaces and grew inward toward the center, now occupying most of the area. In the process, the central area became enriched in Ni and, at a late stage, its center decomposed into bainitic-martensitic plessite (black). This structure is surrounded by a three-layer rim: innermost, a clear taenite zone, followed by a zone of cloudy taenite that in turn is bordered by a thin rim of tetrataenite in contact with the kamacite. Scale bar 400 μm . (Taken from Buchwald, 1975, fig. 2081B.)

comparatively low-density olivine suspended within metal, and their very slow cooling rates. Olivine is a mineral associated with deep-seated earth rocks, and iron meteorites are commonly suggested as coming from the cores of meteorite parent bodies and are viewed as analogues of our core. This has led many to believe that pallasites are analogues of our mantle/core interface. Detailed metallographic analysis has led to the conclusion that pallasites are among the most slowly cooled meteorites (about 1°C per million years), implying that they derive from large parent bodies (Buseck and Goldstein, 1969). Evidence from fission track measurements in pallasitic phosphate minerals has been used to argue for a cooling rate about a factor of ten faster (Pellas et al., 1983), but this is still a slow rate for meteorites. More recent metallographic work has moved these estimates closer together (Saikumar and Goldstein, 1988).

The Imilac pallasite has a long and complex history and a rather inaccessible early literature (Buchwald, 1975:1393–1400; Graham et al., 1985:174). Specimens were first recovered from the Atacama Desert around 1820, and by the late 1850s were in a number of hands in locations throughout western and southern South America, were already widely distributed in European collections, and had even reached Moscow and the United States (Buchner, 1863:127). The ancient Imilac fall was a shower from a large meteoroid (probably at least 500 kg) that entered the atmosphere and broke up, producing a number of large individuals and

thousands of small pieces that were recovered from a relatively small area. Many of the larger masses were recovered early and were rapidly dispersed. As a consequence they were initially described under names and locations peculiar to a particular mass, with little or no concern given for their actual place of origin. Imilac individuals include the two Antofagasta, Chile, individuals; the Gran Chaco and Salta (Figure 2-1) masses from Argentina; and the Ollague, Bolivia, individual to name only a few (Hey, 1966). The full extent of this synonymy has not been recognized until relatively recently (Buchwald, 1975; Scott, 1977), and this has impeded the development of a clear understanding of the range of variation in properties and characteristics within specimens of the Imilac shower.

A crucial point in the consideration of pallasites is that we now understand that in the 1850s only three distinct pallasite falls were known: the historic Pallas Iron from Siberia, now known as the Krasnojarsk meteorite, the Brahin meteorite from Belorussia, and the Imilac, Chile, meteorite already parading under a number of different names and creating the impression that pallasites are more common than they really are. For reasons that will be discussed below, the Krasnojarsk and Brahin meteorites are not possible sources of the Port Orford specimen. Therefore, if Evans' story was fabricated, the Port Orford specimen has to be an Imilac specimen or a previously unknown meteorite.

Examination of Specimens

This section of the paper brings together previously reported observations on the Port Orford specimens and on key Imilac specimens, and adds new data and observations. The examination included the main Port Orford mass (USNM#617) and two polished sections prepared from it, the Vienna specimen, and the Arizona State University (ASU) specimen. The Smithsonian and Vienna specimens are illustrated in the Frontispiece, and the new polished section in Figure 2-3. (Figures 2-4 through 2-7 are mirror images of areas outlined in Figure 2-3b.) This is followed by observations on selected Imilac specimens that will serve later in the discussion of the pairing of Port Orford and Imilac.

The Port Orford specimen as received by Jackson in 1859 (Jackson, 1860) was presumably less than a complete individual, as at least one apparently cut or broken surface would have been necessary to support Evans' claim that this particular piece had been broken off of a much larger mass. Jackson obviously consumed some material for his initial analysis, as he reported that it contained "9 per cent nickel" in the summary of his oral report to the Boston Society of Natural History of 5 October 1859 (Jackson, 1860:161).

The earliest recorded weight of the Port Orford specimen is contained in "a typescript copy of a November 28, 1859 letter from Charles T. Jackson to L. Elie de Beaumont" written shortly after the oral report.⁵ The weight was given as $1\frac{1}{8}$ ounces (31.9 g). Haidinger reported the discovery of the Port

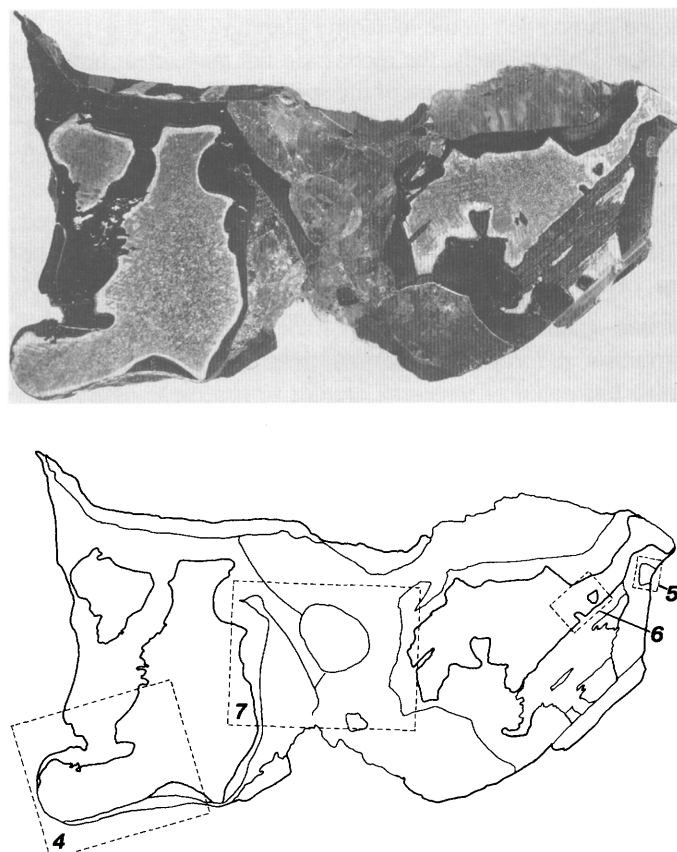


FIGURE 2-3.—Port Orford (USNM#617). Photograph at top is a polished and etched section that was prepared for microscopic examination from a 1.6 g, 2 cm maximum length slice removed from the specimen in 1987. Specimen in Frontispiece is resting on resulting new surface. Areas at left and right are mainly metal, with black to very dark kamacite surrounding plessite. The central and upper right areas are olivine. Index sketch at bottom of figure indicates locations of areas that are discussed in the text and illustrated in following figures.

Orford meteorite to the Academy of Sciences in Vienna, Austria, on 5 July 1860, and in June of the following year reported that Jackson had provided a 3.530 g piece of the pallasite for the Vienna collection (Haidinger, 1860, 1861). This specimen (#A662) was entered into the official register of the mineral collection of the Natural History Museum, Vienna, on 24 October 1861. It was reweighed while on loan to the Smithsonian and was found to be 3.47 g. The ASU specimen weighs 0.9 g, and a 0.19 g piece is reported to be in the collection of the Museum of the Geological Survey of India, Calcutta (Graham et al., 1985:290). A recent report also lists 0.5 g of Port Orford material in the collection of The Natural History Museum, London (Graham et al., 1985, computer disk update of June 1990).

The Smithsonian specimen was acquired from the Boston Society of Natural History in May of 1920 (catalog number USNM#617, accession number 64916) where apparently it had

resided unrecorded in the meteorite literature since the time of Jackson. Unfortunately, the records do not make clear how the Smithsonian became aware of the specimen. Its weight in 1920 was recorded as 25 g. In the early 1960s Henderson and Dole (1964) reported its weight to be 24.2 g. More recently small amounts of material have been removed for study. The polished section used in this study was made from a 1.6 g slice removed in late 1987. The current weight of the main mass is 17.7 g. The sum of these various weights, plus the small amounts of material distributed by the Smithsonian in recent years for study, agrees well with Jackson's weight of 31.9 g.

PORT ORFORD SPECIMEN USNM#617

This Port Orford specimen is highly irregular in shape, with many reentrant angles and cavities (see Frontispiece) and dimensions of $28 \times 25 \times 18$ mm in three perpendicular directions. If massive, these would correspond to a weight of perhaps 50–70 g, so the low weight of only 17.7 g serves to indicate the cavernous nature of the specimen.

The bulk of the Port Orford specimen is metallic, whereas the cavities mainly stem from voids previously occupied by olivine. The metal forms a three-dimensional network enveloping olivine crystals that are estimated to have been 0.5–2.0 cm in diameter, a similar internal structure to that illustrated in Figure 2-1. In protected locations a small amount of olivine (and phosphates) remains.

The Port Orford specimen is unusually well preserved as indicated by the retention of a beautifully developed fusion crust, an uncommon feature on the metal surfaces of meteorite finds. Exterior surfaces that were exposed to atmospheric ablation are coated with the usual variations of warty and striated appearing crust. Its presence was first noted in Haidinger's (1861:2) early report, and he commented that the main mass must be in a good state of preservation. The thickness of the fusion crust ranges from nil to 200 μm and its color varies from glossy black to matte brown. There has been only modest corrosion attack, and it seems that where the fusion crust is missing it is due to human activity, such as scraping or clamping in a vise.

The section that was used for metallographic and electron microprobe investigations is shown in Figure 2-3. The accompanying index sketch indicates areas on this section that are illustrated and discussed below. Nine different minerals and plessite, all of which are known to occur in pallasitic meteorites, are represented in this section: kamacite, taenite, tetrataenite, schreibersite, troilite, chromite, olivine, farringtonite, and stanfieldite.

Sections through the Port Orford fusion crust show it to be a mixture of metallic and nonmetallic phases in a ratio of about 8 : 1. The crust is seen to be rather complex, metallic parts alternating with silicate parts; and sometimes in one and the same location, metal on top of silicate on top of metal (Figures 2-4 and 2-5). The metallic fusion crust is fine grained with

2–20 μm spheroidal inclusions of melted troilite. The silicate fusion crust is complex with numerous tiny metal and troilite particles. The complexity, of course, comes from the pallasitic nature of the meteorite. Being a mixture of coarse grains of

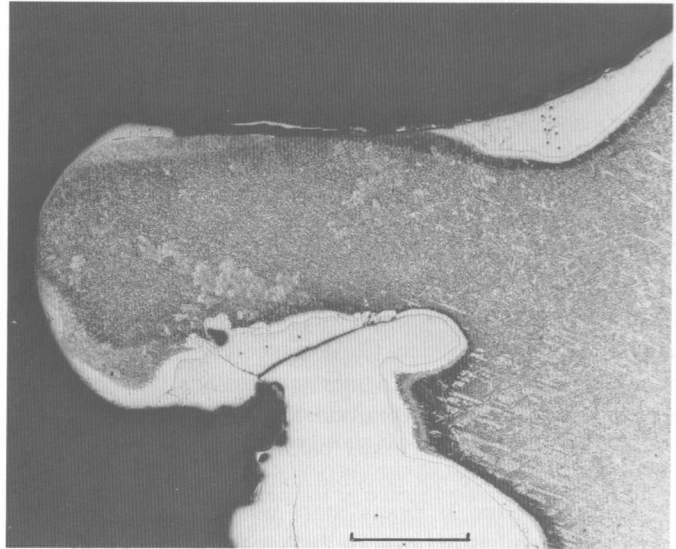


FIGURE 2-4.—Port Orford (USNM#617), enlargement of bottom left portion of Figure 2-3 (mirror image). An etched section of an external surface rounded by atmospheric ablation. Fusion crust still covers the surface irregularly in up to 100 μm thick deposits (above left). Seven square indentions from Vickers hardness determinations are in the kamacite (above right). Most of the field of view is duplex plessite. Scale bar 1 mm.

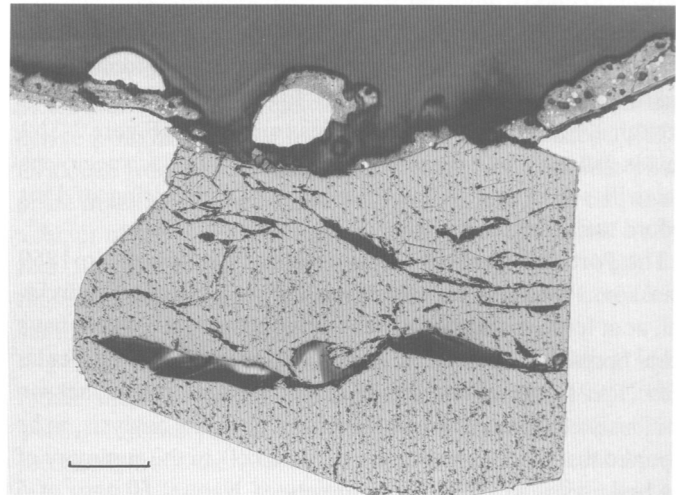


FIGURE 2-5.—Port Orford (USNM#617), detail of upper right edge of Figure 2-3 (mirror image). Along the top edge is a 50 μm thick fusion crust consisting of a mixture of melted olivine, phosphates, oxidized metal, and with spherical inclusions of melted metal. The gray area is one of 6 chromite crystals that have been observed in kamacite, as here, or in farringtonite, as in Figures 2-6 and 2-8. Scale bar 0.1 mm.

TABLE 2-1.—Selected element comparison of oxidic part of the 100–200 μm thick fusion crust on Port Orford with similar fusion crust on Imilac samples. Electron microprobe data with ranges in weight percent.

Pallasite	Si	Al	Fe	Ni	P
Port Orford USNM#617	2.5–5.6	0–0.1	34.7–53.6	1.3–5.3	1.3–7.4
Imilac USNM#6272	3.8–14.7	0–0.1	18.4–43.9	0.6–5.0	0.2–3.7
Imilac USNM#383 (Ilimaes)	2.7–5.4	0–0.1	44.8–53.6	4.5–5.6	0.4–2.1

metal and olivine, with small amounts of troilite, the fusion crust is deposited on olivine crystals as well as on metallic matrix, and in either case all three components may contribute to the composition of the crust.

Typical portions of the fusion crust were subjected to electron microprobe analysis.⁶ The data presented in Table 2-1 confirmed the complexity and the large variations, which are due to varying ratios of melted metal (FeNi), olivine (Si), troilite (Fe), schreibersite (Fe,Ni,P), and phosphates (P). Except for P, the Port Orford values lie within the ranges established by the two Imilac specimens. This local high P content for the Port Orford fusion crust is caused by the presence of phosphates at the ablating surface.

During ablation and fusion crust formation a thermal gradient develops in the metal below the melt zone, resulting in transformations that can be recognized under the microscope. Kamacite is transformed to unequilibrium α_2 to a depth of 0.1–0.5 mm. Locally, where a schreibersite veinlet happens to be located in the exterior part of this heat-affected zone it is micromelted due to the temperature being briefly over 1000° C. The microhardness of kamacite (Vickers at 100 g load) is rather variable because of the unequilibrium state, 185±15. From these observations we may deduce that there was an extreme temperature gradient from the surface toward the interior. Whereas the fused crust was at least 1500° C, the temperature 0.2 mm below the crust (in metal) was about 1000° C, and 0.5 mm below the crust about 700° C. The interior probably was never warmer than about 0° C.

Most of the Port Orford specimen is metal; kamacite, taenite, and plessite. The kamacite contains 7.3–7.5 wt% Ni, and has a microhardness (Vickers at 100 g load) of 167±10. There are numerous, undisturbed Neumann bands in the kamacite, as well as numerous subgrain boundaries, decorated with 1 μm schreibersite crystals, and locally there are minute 1 μm rhabdites (small schreibersites with rhombohedral outline) within the kamacite. The kamacite forms 0.5–1.0 mm wide swathing rims around olivine and the phosphates, as these minerals acted as nucleation sites for kamacite when the high-temperature taenite transformed on cooling.

Plessite fields, which comprise the high Ni portion of the metal matrix, are found in the interior of the metal separated from olivine and phosphates by the kamacite borders. Next to the kamacite is a 1 μm wide yellow rim of tetrataenite, then follows a 3–5 μm wide cloudy zone, then a 3–5 μm yellow

zone that grades into a martensitic zone and finally into a duplex interior (Figure 2-6). The duplex interior is a micro-Widmanstätten pattern of minute kamacite spindles and cells with intercalated taenite veinlets only 0.5–2.0 μm thick. Some plessite fields are developed as open-meshed comb plessite.

Schreibersite occurs occasionally as major crystals up to 100 μm thick and 700 μm long, and more commonly as tiny 10–20 μm veinlets and knobs, both on kamacite grain boundaries and in plessite interiors. It is monocrystalline and only slightly brecciated.

Troilite is not common in the sections available. In one occurrence a 0.6 mm troilite spheroid was attached to olivine and in another a 0.5 mm troilite spheroid was enclosed in kamacite. Both troilites were monocrystalline and slightly deformed as indicated by scarce, narrow deformation twins.

Chromite crystals of small size (0.4–0.6 mm across, Figure 2-5) occur as subangular, cubic blebs at kamacite/olivine or olivine/phosphate interfaces. The chromite contains 8.5–9.0 wt% Al_2O_3 and 6.5–7.5 wt% MgO in solid solution. These values agree well with analyses of Port Orford, Antofagasta, and Ollague reported earlier by Bunch and Keil (1971).

Olivine $[(\text{Mg,Fe})_2\text{SiO}_4]$, the only silicate mineral present,



FIGURE 2-6.—Port Orford (USNM#617), etched section, detail of area near right edge of Figure 2-3 (mirror image). Above, typical development of the plessite fields, duplex kamacite plus taenite alternating with martensitic zones along the high-nickel taenite rims (black). Below, open-mesh comb plessite with a schreibersite crystal to the right of the scale bar. Scale bar 0.3 mm.

occurs as subangular crystals, 0.5–2 cm in size. It is transparent and ranges in color from almost colorless to a very light olive green when viewed in mm-size fragments. Yellowish amber-brown nuances are seen in places where alteration due to corrosion has started. Its chemical composition calculated as the fayalite $[\text{Fe}_2\text{SiO}_4]$ endmember of the fayalite/forsterite $[\text{Mg}_2\text{SiO}_4]$ solid solution series is 12.5% fayalite, a common pallasite olivine composition (Table 2-2). Ca, Al, alkali-metals, P, and Ni were all below the level of detection of the electron microprobe (about 0.1 wt%).

Surprisingly, two different phosphate minerals are present in this recently prepared Port Orford section. With the unaided eye they are indistinguishable from the olivine with which they are intergrown, and they are not easy to distinguish from olivine under the microscope. The phosphates are coarsely crystalline and form 0.3–2 mm rims on areas adjacent to

olivine and kamacite (Figure 2-7a–d).

Farringtonite $[\text{Mg}_3(\text{PO}_4)_2]$ is the more abundant phosphate (Table 2-3, Figure 2-7a,c). It is essentially pure magnesium phosphate with only a few percent divalent Fe replacing equivalent amounts of Mg. The farringtonite contains numerous small spheroidal inclusions, 2–20 μm across, of kamacite and troilite. The second phosphate is the calcium-magnesium phosphate stanfieldite $[\text{Ca}_4(\text{Mg,Fe})_5(\text{PO}_4)_6]$, also containing a small amount of substitutional Fe (Table 2-3, Figure 2-7b,d).

The Port Orford specimen is well preserved and has been stable under museum conditions in contrast to several other pallasites and to a number of iron meteorites that continue to spall and deteriorate indoors. Nevertheless, the initial stages of terrestrial oxidation are present throughout on a microscopic scale. The fusion crust is degenerating, the kamacite/olivine grain boundaries are rich in limonitic veinlets, 10–80 μm thick,

TABLE 2-2.—The composition and shape of olivine (from data of Buseck and Holdsworth, 1977), and indications of the presence (+) or absence (–) of fusion crust and phosphates in Port Orford and three other pallasites. (a = angular, f = fragmented, F = farringtonite, r = rounded, reh = artificially reheated to 800°–900°C by finder, S = stanfieldite, tw = twisted and sheared fragment, W = whitlockite.)

Pallasite	Percent fayalite	Olivine shape micro/macro	Phosphorian olivine	Fusion crust (this study)	Phosphates
Krasnojarsk	12.5	r/r	–	–	–
Brahin	11.5	f/f	+	–	–
Imilac (Imilac)	12.5	r/a	–	+	W,S
Imilac (Antofagasta)	12.5	r/a	–	+	W,S
Imilac (Gran Chaco)	12.5	r/a	–	tw	–
Imilac (Ilimaes)	12.5	r/a	–	+	S
Imilac (Ollague)	12.5	r/a	–	reh	W,S
Imilac (Salta)	12.5	r/a	–	+	W
Port Orford	12.5	r/a	–	+	S,F

TABLE 2-3.—Phosphates in Port Orford (USNM#617) compared with phosphates in other pallasites. Electron microprobe data, corrected. (n.d. = not detected; n.s. = not sought.)

Pallasite	Farringtonite $\text{Mg}_3(\text{PO}_4)_2$						
	FeO	CaO	MgO	MnO	Na ₂ O	K ₂ O	P ₂ O ₅
Port Orford	2.6–2.9	0.10	43.2–44.5	n.s.	<0.03	<0.01	52.5–52.8
Springwater*	4.12	0.09	43.4	0.02	n.d.	n.d.	52.6

Pallasite	Stanfieldite $\text{Ca}_4(\text{Mg,Fe})_5(\text{PO}_4)_6$							
	FeO	CaO	MgO	MnO	Na ₂ O	K ₂ O	P ₂ O ₅	Total
Port Orford	2.3	25.9	21.1	n.s.	<0.03	<0.02	49.8	99.3
Imilac*	2.43	26.2	22.4	0.42	n.d.	<0.03	49.8	101.9
Springwater*	3.72	25.5	21.1	0.56	0.11	n.d.	49.9	100.9

* Data from Buseck and Holdsworth (1977).

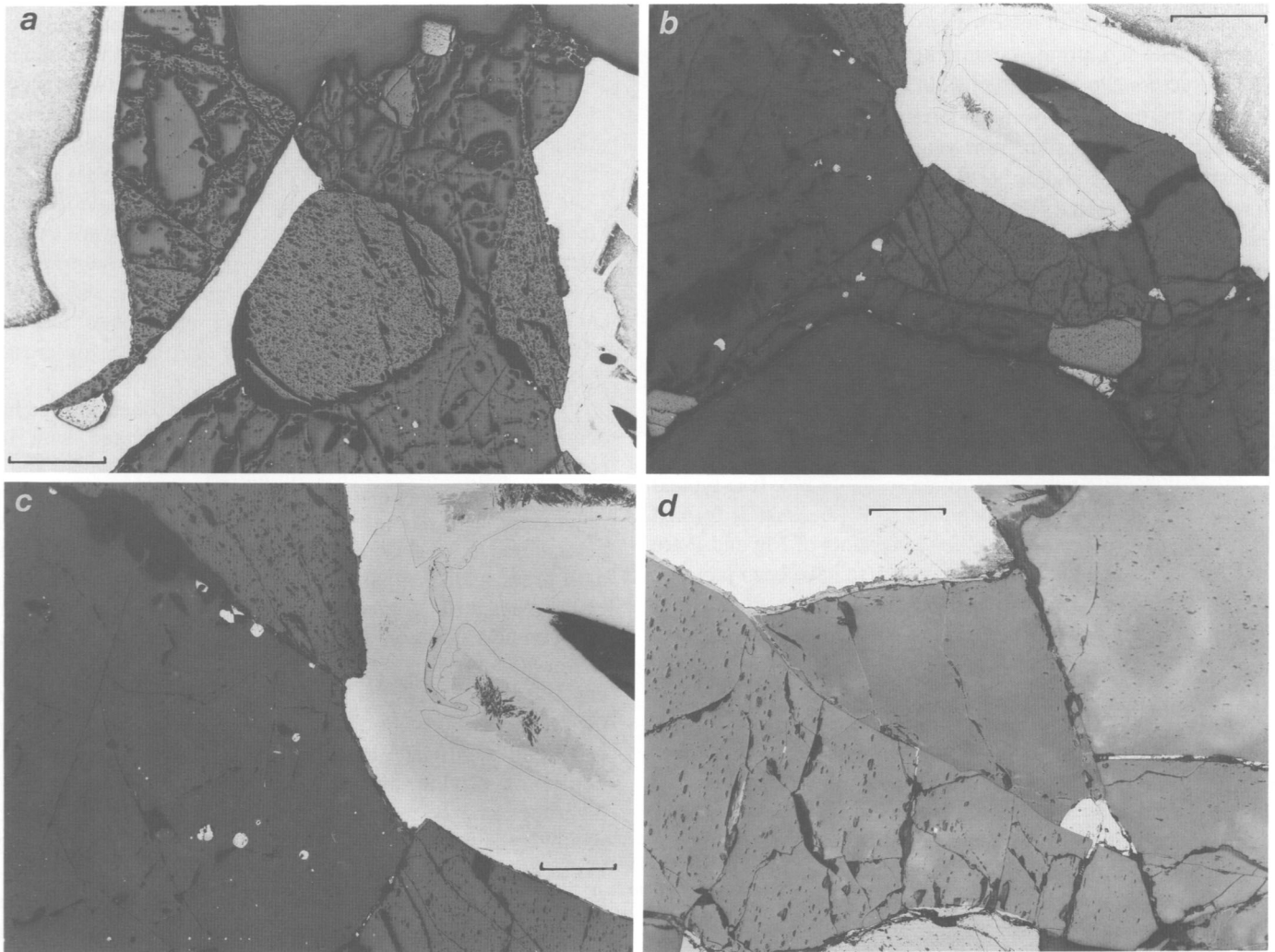


FIGURE 2-7.—Port Orford (USNM#617), polished and lightly etched section; detail of central area in Figure 2-3 (mirror image). *a*, Central rounded and pitted area is the surface of a globule-shape olivine; the lenticular area to its right bordering metal is also olivine. The large dark area with small, apparently white, metal and/or troilite inclusions is farringtonite. White areas are kamacite and the darker metal areas within the kamacite that are not well resolved in this photograph are taenite-plessite areas (Figure 2-6). To the right of center at the top is an almost square chromite inclusion within the farringtonite. The small light colored inclusion above the scale bar is troilite. Scale bar 1 mm. *b,c,d* are enlargements from the lower right hand corner of *a* and slightly beyond: *b*, At center right, crescent-shape olivine encloses metal and a stanfieldite wedge (see also *d*). White areas are kamacite containing taenite-plessite. Farringtonite at left contains metal and/or troilite inclusions. Light gray chromite 0.7 mm long at lower right and a 0.4 mm chromite at lower left. Scale bar 0.5 mm. *c*, Detail of upper center in *b*. Farringtonite to left with metal and/or troilite inclusions, with olivine at top and bottom. Kamacite is white and contains a slightly darker grain boundary schreibersite at its center. The complex structures within the kamacite and associated with the grain boundary schreibersite are taenite-plessite areas containing interior nickel martensite (dark). Scale bar 0.2 mm. *d*, Detail of *b*. A stanfieldite wedge between two differently oriented olivine crystals. Beginning corrosion has attacked the kamacite edges creating veinlets of goethite and akaganéite. Scale bar 0.1 mm.

as are many of the fine cracks through the olivine crystals.

A closer study of the weathering products show the presence of akaganéite and goethite. Akaganéite appears bluish gray on the polished surface and is fiery, orange-red under crossed nicols. It is located at the actively corroding interface with

metal (usually kamacite), where it forms 10–50 μm wide veinlets. Akaganéite recently has been recognized as an important corrosion product in Antarctic meteorites (Buchwald and Clarke, 1989), but this study and studies underway show that akaganéite is omnipresent as an initial step in the

degradation of metal in meteorites.

Akaganéite is chlorine-containing β -FeOOH with a monoclinic structure (Post and Buchwald, 1991). The chloride ions penetrate the meteorite from the terrestrial environment and are attracted to the corrosion front where they may participate in corrosive reactions and/or be incorporated into the akaganéite structure. Incorporated in the akaganéite, the chlorine ions lie in reserve for future attack. When the meteorite becomes wet they are released by an exchange reaction ($\text{Cl}^- \rightleftharpoons \text{OH}^-$) and become available to depassivate the kamacite and participate in another corrosion cycle, possibly becoming incorporated into a later generation of akaganéite.

Akaganéite is metastable and is finally converted to the stable oxide goethite, α -FeOOH, which is also present in the weathered parts of Port Orford. The composition range of goethite/akaganéite veinlets is given in Table 2-4. It is typical that the akaganéite contains significant Ni, because it formed from Ni-containing kamacite. Small amounts of Mg and P are also present, as olivine and phosphates also have been partially decomposed. The accessory Ca and K ions are introduced from the soil. The balance of the analyses is water and hydrogen.

THE VIENNA PORT ORFORD SPECIMEN #A662

For many years the only Port Orford specimen that was known to the scientific community was the small piece that Jackson had sent to Vienna (see Frontispiece). The location of the major part of the specimen that Evans had sent to Jackson was evidently unknown to meteorite workers until the Smithsonian obtained it in 1920. Wülfing (1897:283) cited the published literature on Port Orford and listed 4 g in Vienna, with tiny fragments at Berlin, Calcutta, and in the Museum of Practical Geology, London. Farrington (1915:358-360) also reviewed the literature and quoted extensively from the Jackson/Evans correspondence. He commented that "only 4 grams of the meteorite are known to be preserved. This is in the Vienna collection."

Our physical examination of the Vienna Port Orford specimen was not as exhaustive as that of the larger mass, but where comparable observations were possible agreement was

excellent. The two pieces give every appearance of being from the same initial mass, but by placing the two together it did not prove possible to suggest a spatial relationship between them.

The specimen has a sawn surface of $\sim 0.4 \text{ cm}^2$ that had been polished and etched in the past and appears to be the same surface that was described and illustrated by Brezina and Cohen (1886). Sitting on this cut surface, the specimen has five other readily discernable surfaces. Four of these were exterior surfaces during atmospheric passage and are about 80% covered with a thick fusion crust. The fifth is the surface of a cavity that contained a cm-size olivine. Three mm-size olivine-containing areas are exposed on the fusion-crust surfaces.

The previously etched surface was repolished and etched (Figure 2-8), and examined microscopically and with the electron microprobe. The surface is edged in kamacite and is dominated by three plessite regions. The edge in the top of the photograph is an original exterior surface that has been heat-altered to martensite (α_2). The three closely spaced, small dark areas at the upper left are olivine. The crescent-shape embayment in the kamacite 3 mm SSE of the small olivines also contains olivine (difficult to recognize at this exposure). Below this embayment is another small embayment that contains chromite. Within the kamacite area on the right side of the specimen and protruding into the plessite is an olivine 1 mm in length. Across the kamacite from this inclusion is a thin border of olivine over 2.5 mm long. Two schreibersite inclusions may be recognized in the kamacite at the top of the photograph, and two other schreibersite areas are in the large kamacite area at the lower right. One of these schreibersites is bordering the plessite area. The details of the plessite areas are as described above. Olivine and chromite compositions were measured on the electron microprobe, and within reasonable margins of error, are indistinguishable from compositions reported for USNM#617.

THE ARIZONA STATE UNIVERSITY, PORT ORFORD SPECIMEN #1100

Howard Plotkin⁷ called our attention to a letter of 22 December 1863 from C.U. Shepard⁸ to C.T. Jackson requesting

TABLE 2-4.—Comparison of the weathering products (goethite and akaganéite) on Port Orford; Imilac; Willamette, Oregon; and Uwharrie, North Carolina, specimens.

Pallasite	Cl	Fe	Mg	Ca	K	Ni	P
Port Orford USNM#617	0.1-0.5	43.5-56.0	0-0.3	0-0.1	0-0.2	2.6-8.9	0-3.0
Imilac USNM#6272	0-1.1	47.9-54.7	0-0.3	0-0.4	0-0.2	1.7-5.0	0-1.1
Imilac USNM#383 (Ilimaes)	0.2-0.5	49.3-57.4	0.1-0.6	0.2-0.5	0.2-0.5	1.8-5.6	0.1-0.2
Imilac USNM#956	0-0.1	46.4-50.1	0-0.2	0-0.7	<0.05	2.5-8.0	0-2.1
Willamette USNM#333	17-19	49-50	<0.05	<0.05	<0.05	0.5	<0.05
Willamette USNM#333	2.9-5.1	45-52	<0.05	<0.05	<0.05	5-7	<0.1
Uwharrie USNM#850.1	4.8-5.6	49.2-50.9	<0.05	<0.05	<0.15	0.3-0.6	<0.05

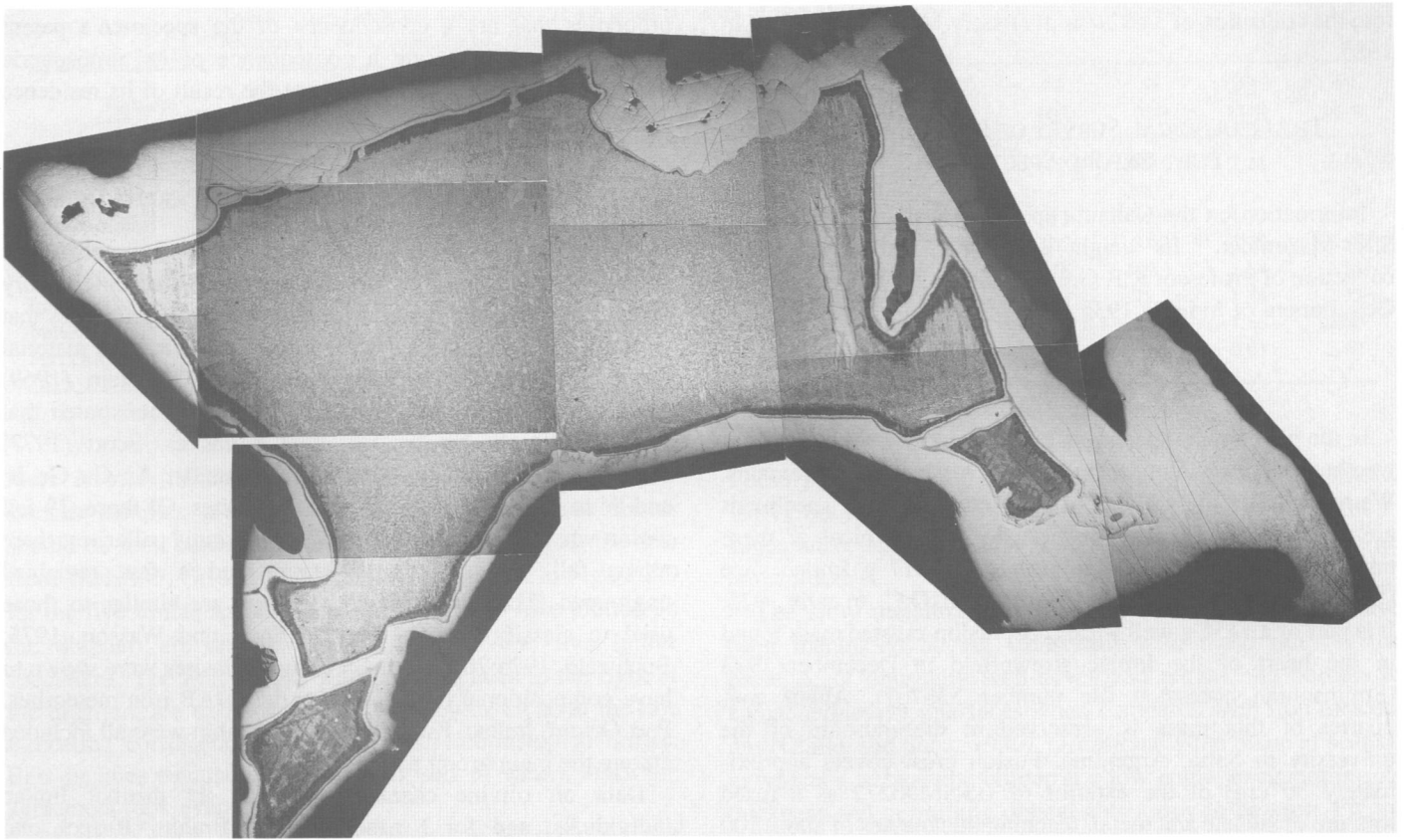


FIGURE 2-8.—Photographic mosaic of etched surface of the Vienna Port Orford specimen #A662. Kamacite borders areas of plessite, and overall metallography is identical to that of the Smithsonian Port Orford sample. Olivine, schreibersite, and chromite may be seen on close inspection. Maximum width 1.3 cm.

a piece of the Port Orford meteorite because the Oregon Territory was so poorly represented in his collection. Presumably Jackson granted the request by sending a small amount to Shepard. A major part of Shepard's meteorite collection went to Amherst College, and the Amherst collection eventually went to Arizona State University, Tempe.

The specimen consists of two small pieces of metal (588 and 232 mg), several olivine crystals and fragments (46 mg), and a small amount of debris (47 mg). The larger piece of metal is a fish-shape slice 14 mm in length and 1–3 mm thick. The larger of the two surfaces has been deeply etched revealing a pallasitic metallic structure. The other surface is rough sawn. One edge of the slice is an exterior surface that is about 40% fusion crusted. Small fragments of olivine and chromite adhere to the other, interior edge. The smaller piece of metal is also exterior surface material that is fusion crusted, revealing considerable aerodynamic detail. The olivine crystals are pale yellow and water clear. The fine debris contains smaller fragments of olivine, chromite fragments, chips of fusion crust, corrosion products, cutting residues, etc. Everything that was observed using a

low-power microscope indicates that this material is similar in every way to the other Port Orford specimens.

THE NATURAL HISTORY MUSEUM, LONDON,
PORT ORFORD SPECIMEN #1985,M.187

This specimen was not examined by us. The information given here is a summary of available documentation provided by Dr. Andrew L. Graham.⁹

The specimen is not recorded in the catalogue of the collection of meteorites in the possession of W. Nevill, FGS, Godalming, Surrey dated 3 October 1867. It is, however recorded in the catalogue of meteorites in the Nevill collection dated May 1872, as Rogue River but no weight is reported. This collection was purchased by H Ludlam in about 1876. The Rogue River specimen is included in the catalogue of the Ludlam-Nevill collection of meteorites in the possession of H Ludlam, 174 Piccadilly, London which is not dated but was printed in about 1876. This collection was bequeathed to the Museum of Practical Geology (forerunner of the Geological Museum) in 1880.

The specimen now weighs less than 0.5g and consists of numerous small fragments of olivine and rusting metal.

The collection of the Geological Museum was incorporated

into the collection of The Natural History Museum, London, in 1985.

THE GEOLOGICAL SURVEY OF INDIA, CALCUTTA,
PORT ORFORD SPECIMEN #I 1

Information on the Calcutta specimen was provided by Dr. S.K. Mazumder.¹⁰ Its weight is 0.194 g, and it was in the collection of Professor R.P. Gregg, which was purchased by the Government of India in 1935.

IMILAC SPECIMENS

In the past, Imilac specimens have tended to be thought of as weathered to the point where fusion crust no longer remains. We now realize that although fusion-crust Imilac specimens are not common, good examples do exist. Typical of these unusually well-preserved samples is the 217 g Imilac slice (USNM#6272) that arrived in Washington, D.C., in early 1975. It is part of a 1255 g well-preserved, fusion-crust mass found in the heart of the Imilac strewnfield in December 1973 (Smithsonian accession file number 356767). About one-quarter of this mass is preserved in the museum of the university in Salta, Argentina. Fusion crust covers approximately 50 cm² of the exterior of USNM#6272 as a fused mixture of silicate and metal, reaching thicknesses of about 100 μm (Table 2-1). Under the fusion crust is a heat-affected α_2 zone that is 500 μm thick.

On the two Imilac specimens (USNM#383, cataloged under the name Ilimaes) of 66 g and 3.6 g, distinct fusion crust, up to 200 μm thick, covers significant parts of the surface (Table 2-1), whereas the remaining surface is clearly one of fracturing, mainly through olivine. Under the fusion crust are heat-affected α_2 zones 0.5–1.2 mm thick, with micromelted phosphides in the exterior half.

Fusion crust and well-preserved olivines also are present on a 193 g Imilac specimen (USNM#8) and on several smaller Imilac samples that were collected by Buchwald in 1973. There is no doubt that a certain proportion of the "exploding" Imilac main mass survived very well, with only limited destruction of the olivine and with development of beautiful fusion crust and thin heat-affected zones. Some of these fragments also survived the weathering attack very well, probably because they were not buried but exposed on some rock surface.

Discussion

As stated above and discussed in greater detail below, it is most unlikely that the Port Orford specimen could have come from either the Krasnojarsk or the Brahin falls. Imilac, therefore, is the only pairing possibility. Presented here is a discussion of the data and observations that bear on Port Orford/Imilac pairing with a subsequent discussion of the other two meteorites. This section is organized loosely under

properties that are a consequence of the specimen's parent body, properties that are a consequence of its atmospheric passage, and characteristics that are the result of its residence on the Earth's surface.

CHARACTERISTICS DERIVED FROM THE PARENT BODY

The compositions of major and minor minerals, their petrographic relationships, and the meteorite's cooling history as revealed by metallographic structures are all properties that derive from the asteroidal parent body in which the material formed. Mason (1963) and Buseck and Goldstein (1969) defined pallasite olivine compositions and demonstrated that they are closely similar for most pallasites. Scott (1977) measured Ni and Co, and the trace elements Au, As, Ga, Ge, Ir, and W in the metal of 28 different pallasites. Of these, 19 fell within what Scott defined as the "main group" pallasites, three others fell into a separate group, and a few remained ungrouped. These classification groups are similar to those used to classify iron meteorites (Scott and Wasson, 1975; Buchwald, 1975:70), and main group pallasites were shown to have compositional relationship to the IIIAB iron meteorites. Port Orford, Imilac, Krasnojarsk, and Brahin were all included among the main group pallasites.

Data on olivine characteristics for six distinct Imilac individuals, and for Krasnojarsk and Brahin (Buseck and Holdsworth, 1977), are summarized in Table 2-2 and compared with our data for Port Orford. In the first column, the names in parentheses following Imilac are the synonyms used by the authors, names under which these specimens were long known in the literature. In contrast to Brahin, none of the Imilac specimens is known to have phosphorian olivine.

A comparison of Ni and Co contents with the main trace elements in the metal of Imilac and Port Orford specimens is given in Table 2-5. Both Davis (1977) and Scott (1977) have published similar data sets for these pallasites, but we have chosen to use only Davis' data as it is more extensive and it enables us to avoid the problems of interlaboratory differences. Included in his survey were Imilac and four other South American pallasites, Antofagasta, Ilimaes, Ollague, and Salta. These four pallasites have been shown by Buchwald (1973, 1975) and Scott (1977) to be fragments of the Imilac shower, and they permit us to interpret Davis' data as sampling five different pieces of the Imilac fall.

These data show variability with respect to both Ni and trace elements, but there is a clear pattern for the Imilac specimens. For example, Au and Cu are positively correlated with Ni, whereas Ge and As are negatively correlated with Ni. This may be interpreted, at least in part, as a consequence of having analyzed samples with slightly different ratios of kamacite to plessite, which may easily happen when working with samples as small as 60–100 mg. The swathing kamacite/taenite-plessite proportions may then easily vary from sample to sample. Higher Ni values would be observed in samples richer in the

TABLE 2-5.—Elemental composition of the metallic matrix of Port Orford, compared to that of the pallasites Krasnojarsk, Brahin, and Imilac. Neutron activation analyses by Davis (1977, table III-7).

Pallasite	Ni wt%	Co ppm	Cu ppm	Ga ppm	Ge ppm	As ppm	Pd ppm	Os ppb	Ir ppb	Pt ppm	Au ppm
Krasnojarsk	8.9	6170	101	22.9	56.1	28.1	4.41	97.4	200	2.16	2.48
Brahin	9.2	5630	140	23.3	—	26.9	—	—	98	—	2.63
Imilac (Imilac)	9.6	5670	131	23.1	48.3	24.4	4.61	91	80.9	1.77	2.40
Imilac (Antofagasta)	10.1	5200	141	22.4	46.0	20.9	5.38	107	94.2	1.79	2.56
Imilac (Ilimaes)	10.4	5430	141	22.4	39.9	21.4	5.02	125	112	1.64	2.52
Imilac (Ollague)	9.2	5950	133	23.1	46.2	25.8	4.19	103	75.5	1.84	2.37
Imilac (Salta)	8.9	5900	109	21.8	51.0	25.5	4.19	124	83.8	1.56	2.30
Port Orford	11.3	5470	202	21.2	34.1	22.8	5.29	102	82.1	0.93	2.62

more Ni-rich taenite-plessite areas. If under these circumstances samples are genetically related, systematic trends should be seen between Ni and other elements. Using the data from Table 2-5, Ge and Au are plotted against Ni in Figure 2-9 for the five Imilac specimens and Port Orford. Also plotted on the diagram are simple best-fit lines for the five Imilac specimens. The Port Orford values, the squares to the right of the diagram, are extreme values, but they lie close to the line indicating consistency with a genetic relationship to Imilac. Best-fit lines calculated using all six sets of values make the agreement look even better.

The phosphates known to be present in Port Orford and Imilac specimens are listed in Table 2-2. Stanfieldite has been reported in four other Imilac specimens, and the Port Orford and Imilac stanfieldite compositions are closely similar (Table 2-3). Farringtonite has not been reported previously from Imilac, a fortuitous occurrence, but not a reason to claim separate origins. Its composition agrees well with that previously reported for the Springwater pallasite (Table 2-3).

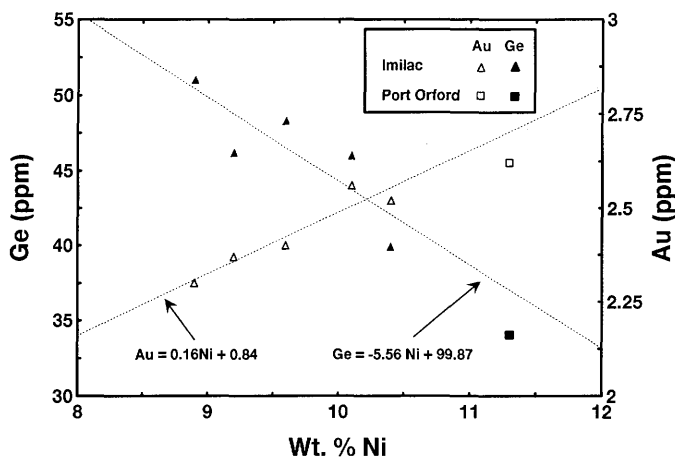


FIGURE 2-9.—A plot of Ni versus Ge and Au concentrations for 5 Imilac specimens (triangles) and the Port Orford specimen (squares) using the values of Davis (1977, table 5). Simple best-fit lines for the 5 Imilac specimens are also given.

These phosphates are known in other pallasites (Buchwald, 1984), but they are distributed erratically, similar to olivine in appearance, and are easily overlooked and, hence, may go unrecorded.

The slow metallographic cooling rates of pallasites have been mentioned above. Consistent with these rates is the presence of unusually well-developed tetrataenite borders at kamacite/plessite interfaces when compared with iron meteorites (Clarke and Scott, 1980). Occasionally the plane of section intersects a tetrataenite border at a low angle, exaggerating its thickness and permitting optical anisotropy to be seen. Figure 2-10 is an example of this in the Port Orford meteorite. The anisotropy that is seen, perhaps with some difficulty in Figure 2-10b, is actually much more dramatic under the microscope due to color differences. The presence of anisotropy establishes that this border is tetrataenite, ordered FeNi, and not compositionally similar disordered taenite. The presence of tetrataenite is evidence that the interior of the Port Orford specimen has not been severely shocked, nor has it been exposed to mild heating for modest periods of time or to severe heating for a short time.

PROPERTIES RELATED TO ATMOSPHERIC PASSAGE

Fusion crust overlying heat-altered zones on the surfaces of the Port Orford specimen are remnants of ablative passage through our atmosphere. We have noted above that although the Imilac shower generally has not been recognized as producing fusion-crust specimens, there actually are a small number of very well-preserved and fusion-crust Imilac specimens known. Heat-altered zones have been observed on many small Imilac specimens.

Possibly the first description of a fusion-crust Imilac specimen was given by H.A. Ward (1906:226). He described the 95 kg Ilimaes mass as follows:

The main portion of the exterior was covered by a thick coating of melted matter, or crust, which was broken by several areas of several square inches each. ... The thickness of the crust is from 0.3 to 0.5 mm., being thicker above the stony than above the iron part of the mass. ... Quite exceptional among all

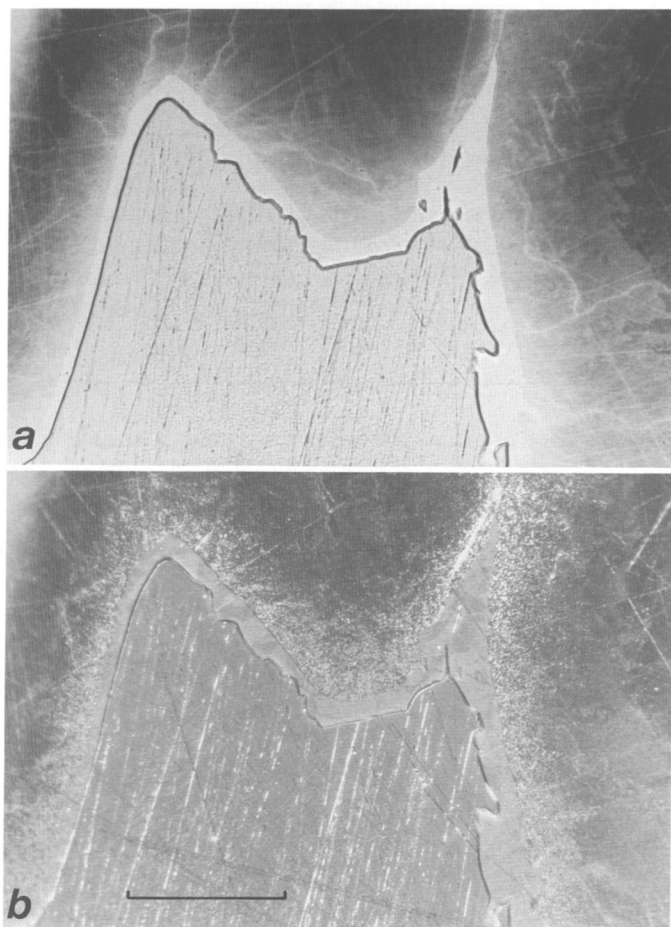


FIGURE 2-10.—Port Orford (USNM #617). *a*, The top and sides, grading from dark to lighter shades of gray, is cloudy taenite. The large, light gray area containing scratches and bordering the bottom of the photograph is kamacite. The black line edging the white border separating kamacite from the cloudy taenite is an optical effect. This 3–20 μm thick border is tetraetaenite. *b*, Partially crossed Nicols. The patchiness in the tetraetaenite is due to optical anisotropy. Oil immersion, scale bar 50 μm .

the pallasites with which the writer is acquainted, although approximated by Marjalahti, is the thickness and firm investment of this outer crust.

The accompanying photograph (Ward, 1906, plate 23) persuasively supports this description, as does the comparison with fusion crust on the Marjalahti pallasite. Fusion-crust Marjalahti material was recovered promptly after a single individual fell in Karelia in June 1902 (Graham et al., 1985:227). Ward's observations, however, had not been integrated into the general understanding of the Imilac shower because the Ilimaes specimen only recently has been recognized as an Imilac individual (Buchwald, 1975:1393).

Particularly influential in our thinking on linking Port Orford fusion crust to fusion crust on Imilac specimens was the Imilac specimen USNM#6272 discussed above. It has well-developed, fresh-appearing fusion crust, and it was collected in

the strewnfield as late as 1973. If a specimen that well preserved was found at such a late date, Evans might well have obtained a similar one in the late 1850s. Having a choice, anyone with an eye for geologic specimens would naturally select the fresher appearing and more attractive fusion-crust material.

The fusion crust/heat-altered zone association on the Port Orford specimen clearly speaks to its origin as an individual from a shower producing meteorite. The 0.5 mm heat-altered zone underlying Port Orford's fusion crust represents a steep thermal gradient when compared to the typically 2 mm thick heat-altered zones on meteorites that penetrated the atmosphere as single, unbroken bodies. These meteorites, for instance, contain micromelted phosphides to a depth of 1 mm, indicating the 1000°C contour. On both the Port Orford and the many small Imilac specimens examined, the surface temperature was lower. The phosphides did not melt, and the complete zone where ablative effects can be recognized metallographically is narrower than the 1000°C contour on meteorites that penetrated as individuals. These steep gradients are typical of meteorites that passed through much of the atmosphere incorporated in larger bodies that experienced late breakup, producing many smaller individuals to continue in ablative flight into the lower atmosphere. The shape and size of the Port Orford specimen as we know it fits with the gradient to show that it originated as a small piece by rupture of a larger body in the upper atmosphere and penetrated only the lower atmosphere as an independent body. It was probably initially an egg-size fragment. During the ensuing brief and violent period, the projectile's extraterrestrial kinetic energy was absorbed by atmospheric compression and the resulting frictional surface heating. Surface material was melted and removed in successive thin layers, and some of the olivine that survived the initial disruption was lost. Within only a second or two its kinetic energy was absorbed, leaving an ~30 g fusion-crust nucleus, essentially unheated a few hundred microns below its surface, to free-fall the remaining few kilometers for a comparatively gentle landing.

Numerous small Imilac specimens exhibit distorted and sheared structures (Figure 2-11). On the exterior faces there may be distinct fluting and shearing, sometimes to the effect of creating wedge-shape fragments, bounded by two shear surfaces. When the specimens are examined on a metallographic section taken perpendicular to the shear face, the structural elements are seen to be visibly bent and dislocated as illustrated in Figure 2-12. Originally coherent taenite ribbons may be cut across and dislocated 0.2–0.5 mm relative to each other. The brittle schreibersite crystals are broken and dislocated in a series of steps, producing offsets of 1–25 μm .

These changes are due to the final violent deceleration and breakup of the incoming meteoroid within the atmosphere. Breakup of the mixture of olivine crystals and metal occurs when the metallic bridges shear. The shearing also severely damages and fissures olivine, schreibersite, and phosphates,



FIGURE 2-11.—Imilac (Copenhagen). Six fragments of the shower weighing 5-15 g each, collected on the site in the Atacama Desert, Chile, by V.F. Buchwald in 1973 (Buchwald, 1975:1395). The Port Orford specimen is similar to these but with better-preserved fusion crust and less deformation. Scale in cm.

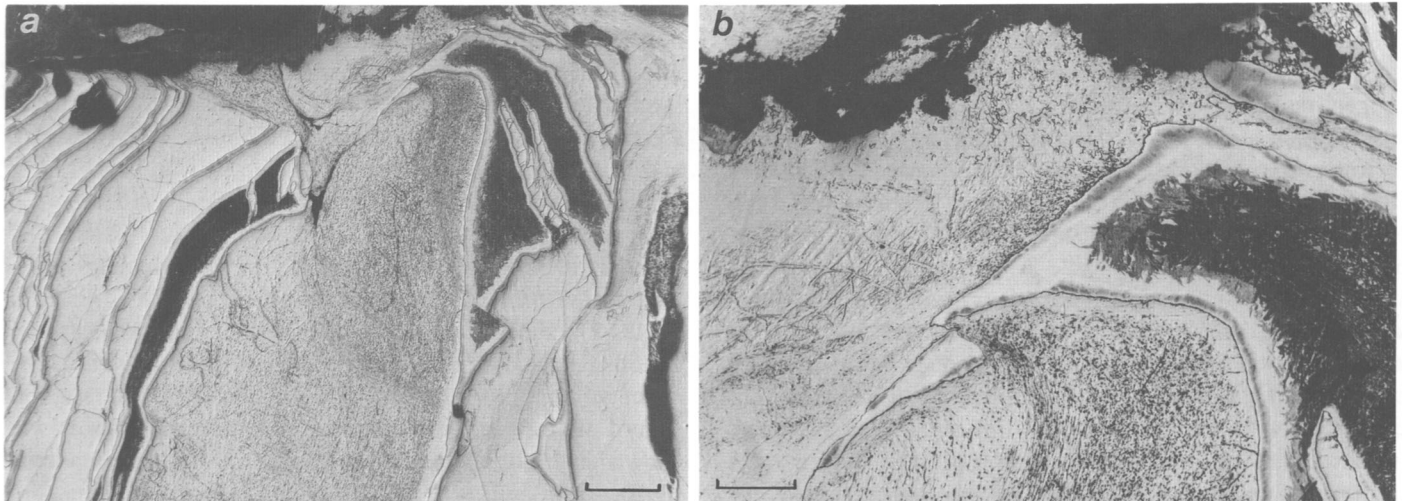


FIGURE 2-12.—Imilac (Copenhagen). *a*, A section through one of the distorted fragments (20 g) from the strewnfield. Plastic deformation is visible along the top edge, and a shear zone has dislocated the taenite in the right side of the picture (Buchwald, 1975:1396, fig. 2082). Scale bar 400 μm . *b*, Detail of *a*. Distorted metal is indicated by the slip lines in the kamacite (gray) and the over-bent taenite and plessite fields. Corrosion rims the top edge (solid black), but some of the heat-affected α_2 zone formed during atmospheric flight has been preserved (granular gray). Scale bar 100 μm .

which later easily disappear by the combined action of terrestrial corrosion and erosion (Figure 2-12).

The Port Orford specimen is damaged by shearing only to a

very limited extent, suggesting that it separated from the incoming meteorite rather early and did not participate in the final violent breakup.

WEATHERING HISTORY

The extent of corrosion to which the Port Orford specimen has been subjected indicates that it is clearly not a recent fall, but one that has resided for some time in a mildly corrosive environment. In Table 2-4 electron microprobe data are presented on the goethite/akaganéite areas found at various localities on the Port Orford section and on three different Imilac sections. Data also are given for corrosion products on the iron meteorites Willamette, found in Oregon, and the Uwharrie, found in North Carolina. Because Port Orford was said to have been derived from Oregon, the data from Willamette, which was found in a forested region not very far from the mythical Port Orford location, may be of particular value for comparison.

Corrosion products in similar locations on specimens from the Imilac shower and Port Orford are seen to have similar compositions. On the other hand, corrosion products in similar locations on Willamette are characterized by much higher Cl contents. The Willamette corrosion-product composition is, in turn, similar to that observed for Uwharrie, both meteorites having weathered in wet, temperate zone climates. Imilac corrosion products are characteristic of long-time exposure to the arid conditions of the 3000 m high desert location in North Chile. As the Port Orford corrosion products are identical to those on Imilac specimens, it must be concluded that Port Orford weathered, and was therefore found, in a desert environment and not on the humid slopes of some western Oregon mountain.

A foreign particle was noted in the akaganéite/goethite corrosion crust of Port Orford. The particle comes from the soil where Port Orford was weathered and remained with the meteorite engulfed in its corrosion products. The composition of this particle is given in Table 2-6 and compared with five similar particles found in the corrosion products of an Imilac specimen. Although there is no direct correspondence, it appears that all six particles are of a feldspathic nature and could have derived from a weathering granite or gneiss terrain, consistent with the recovery site of the Imilac meteorite (Buchwald, 1975:1397). On the other hand, this association is inconsistent with the specimen having weathered in the geologic setting of the Port Orford, Oregon, area.

OTHER POSSIBLE PAIRINGS

As mentioned above, there were only three individual pallasite finds known in the 1850s: Krasnojarsk, Imilac, and Brahin (Tables 2-2 and 2-5). Is it possible that the Port Orford specimen can be paired with either Krasnojarsk or Brahin? The Krasnojarsk meteorite is the historically important Pallas Iron found in Siberia in 1749. Samples were sawn and broken from this single 700 kg mass in the early 19th century and distributed all over the world to museums and the serious collectors of the day. In his initial announcement of the Port Orford meteorite, Jackson (1860:161) noted similarities between Port Orford and the Krasnojarsk meteorite. He suggested that they might be two pieces of the same shower separated by an unusually wide distance, a distance that is considered unacceptably great today.

The compositions of Krasnojarsk metal and olivine are presented in Tables 2-2 and 2-5. None of the many Krasnojarsk specimens examined by us have fusion crust and we know of no literature reports of fusion crust. They are more corroded than Imilac specimens and their corrosion differs in detail, suggesting corrosion in a more humid environment. In addition, phosphates have never been reported in Krasnojarsk. However, the shape of the olivine grains is rounded, both on a macroscopic and a microscopic scale, and they resemble the olivines of Port Orford.

Brahin was found in 1810 in Belorussiya, but apparently was not distributed very much outside of Russia in the 19th century. The British Museum collection still contains only 28 g and the Smithsonian Institution collection only 19 g. Similar small specimens reached other collections, whereas Vienna, Berlin, and Paris fared better with 3320 g, 313 g, and 218 g respectively (Buchner, 1863:129; Wülfing, 1897:41, 42; Graham et al., 1985:80). It is highly unlikely that small individuals of Brahin were available in the Americas in the 1850s. The composition of its metal and olivine is given in Tables 2-2 and 2-5. Brahin specimens are corroded, have no fusion crust, and phosphates have not been reported. The shape of the olivine grains is fragmental and very different from Port Orford olivines, and the olivine is rich in phosphorus as was shown by Buseck and Holdsworth (1977), an important distinction.

In our judgment, it is impossible that the Port Orford

TABLE 2-6.—A foreign particle embedded in the weathering crust of Port Orford compared to similar particles in the weathering crust of Imilac specimens. Electron microprobe data in weight percent. (n.s. = not sought.)

Pallasite	Si	Al	Fe	Mg	Ca	K	Na
Port Orford USNM#617	30.1	6.4	5.2	0.5	0.3	1.2	n.s.
Imilac USNM#6272a	29.6	10.9	3.5	0.2	0	12.0	n.s.
Imilac USNM#6272b	28.6	6.3	13.2	0.1	0.3	4.0	n.s.
Imilac USNM#6272c	40.0	6.9	2.1	0.1	0	3.7	n.s.
Imilac USNM#6272d	23.8	8.9	7.0	1.9	3.6	0.6	4.7
Imilac USNM#6272e	25.8	11.3	5.4	1.4	2.4	1.6	3.6

specimen came from either the Krasnojarsk or the Brahin meteorites.

Conclusions

On the basis of the physical examination and known chemical properties of the Port Orford meteorite specimens, it is possible to outline its terrestrial history in some detail. It is a main group pallasite that is chemically, structurally, and morphologically indistinguishable from the Imilac pallasite. Port Orford's fusion crust and heat-altered zone clearly label it as a small individual that entered the atmosphere within a larger mass that ruptured and produced a shower of individual meteorite specimens. This rules out the possibility that the Port Orford specimen was a piece removed from a much larger mass as Evans had claimed, and proves that he lied on an utterly fundamental point. At first glance the extent and nature of Port Orford's terrestrial corrosion indicate that either it has been exposed to a humid terrestrial environment for a very short time, such as in the mountains along the Oregon coast, or it has been on the ground for a long period in an arid environment, such as that of the Imilac, Chile, strewnfield. A closer study of the specimen, however, reveals tell-tale signs that indicate that the meteorite is clearly not from a recent fall, but has weathered for some time in a mildly corrosive environment. A few Imilac specimens are as well preserved as the Port Orford specimen. This forces us to conclude that the Port Orford specimen is either an Imilac individual or the only individual ever to have been recovered from a pallasite shower virtually indistinguishable from Imilac. This latter possibility, however, strains credulity.

Imilac specimens were in circulation during Evans' time, and it certainly is possible that he could have acquired one. Other evidence reinforces this conclusion. In particular, Port Orford's overall shape and size, its hardness, the shape and compositions of its olivine grains, the composition of its phosphates, its terrestrial corrosion products, and its adherent soil particles all lend convincing support to the conclusion that

the Port Orford meteorite is actually a specimen from the Imilac shower. The trace element data are consistent with this conclusion. Although they do not by themselves lead to a Port Orford/Imilac pairing¹¹ and are still controversial, they are sufficiently similar to suggest a basic chemical relationship between the two meteorites. Considering all of these factors in concert with the evidence Plotkin (1992) has marshaled convinces us that the Port Orford meteorite is an Imilac specimen and that Evans perpetrated a deliberate hoax using an individual from the Imilac shower as bait.

Notes

¹In a letter of 21 December 1990 to Roy S. Clarke, Jr. (RSC), Richard Pugh, a student of and longtime friend of Erwin F. Lange, wrote that "it was my feeling that after a quarter of a century of phone calls, letters and all his research Dr. Lange was having reservations about the existence of the Port Orford meteorite."

²Smithsonian Institution Archives, Record Unit 7177, Box 17.

³Letter in the Port Orford file in the Division of Meteorites, National Museum of Natural History, Smithsonian Institution.

⁴Letters from E.P. Henderson to A. Wetmore, Smithsonian Archives, Record Unit 305. Howard Plotkin called these to the attention of RSC in a letter of 6 June 1989.

⁵Plotkin supplied this information in a letter of 22 January 1990 to RSC.

⁶The ARL SEMQ electron microprobe in the Department of Mineral Sciences, National Museum of Natural History, Washington, D.C., was used for these and all subsequent analyses reported in this paper.

⁷Letter of 22 January 1990 from Plotkin to RSC.

⁸C.U. Shepard (1804–1896) was a professor of natural history at Amherst College. He started collecting meteorites in about 1840, an activity that continued throughout his life. He described many meteorites and assembled "what was to become the finest mineral collection in the United States in the nineteenth century" (Burke, 1986:201). Part of his meteorite collection, 217 specimens, came to the Smithsonian Institution in 1886 and was ultimately bequeathed to the Smithsonian by his son, Professor C.U. Shepard, Jr., of the Charleston Medical College, Charleston, South Carolina, in 1915 (Merrill, 1916; mason, 1975:8).

⁹Letter of 2 August 1990 from A.L. Graham to RSC.

¹⁰Letter of 27 August 1990 from S.K. Mazumder to RSC.

¹¹In a letter of 31 January 1991 to RSC, Andrew M. Davis describes unpublished work based on his pallasite data base. It is his opinion "that the Ru and Pt data exclude the possibility that Port Orford is part of Imilac."

Literature Cited

- Brezina, A., and E. Cohen
 1886. *Die Structur und Zusammensetzung der Meteoreisen erläutert durch photographische Abbildungen geätzter Schnittflächen*. Part I, plates 1-9 [unnumbered pages]. Stuttgart: E. Schweizerbart'sche Verlagshandlung.
- Buchner, O.
 1863. *Die Meteoriten in Sammlungen*. 202 pages. Leipzig: Verlag von Wilhelm Engelmann.
- Buchwald, V.F.
 1973. The Pallasite Imilac, Chile. [Abstract.] *Meteoritics*, 8:333-334.
 1975. *Handbook of Iron Meteorites*. Volumes 1-3, 1418 pages. Berkeley: University of California Press.
 1984. Phosphate Minerals in Meteorites and Lunar Rocks. In J.O. Nriagu and P.B. Moore, editors, *Phosphate Minerals*, pages 199-214. New York: Springer-Verlag.
- Buchwald, V.F., and R.S. Clarke, Jr.
 1989. Corrosion of Fe-Ni Alloys by Cl-Containing Akaganéite (β -FeOOH): The Antarctic Meteorite Case. *American Mineralogist*, 74:656-667.
- Bunch, T.E., and K. Keil
 1971. Chromite and Ilmenite in Non-Chondritic Meteorites. *American Mineralogist*, 56:146-157.
- Burke, J.G.
 1986. *Cosmic Debris*. 445 pages. Berkeley: University of California Press.
- Buseck, P.R.
 1977. Pallasite Meteorites—Mineralogy, Petrology and Geochemistry. *Geochimica et Cosmochimica Acta*, 41:711-740.
- Buseck, P.R., and J.I. Goldstein
 1969. Olivine Composition and Cooling Rates of Pallasitic Meteorites. *Geological Society of America Bulletin*, 80:2141-2158, 2 plates.
- Buseck, P.R., and E. Holdsworth
 1977. Phosphate Minerals in Pallasite Meteorites. *Mineralogical Magazine*, 41:91-102.
- Clarke, R.S., Jr., and E.R.D. Scott
 1980. Tetrataenite—Ordered FeNi, a New Mineral in Meteorites. *American Mineralogist*, 65:624-630.
- Davis, A.M.
 1977. *The Cosmochemical History of the Pallasites*. 285 pages. Doctoral dissertation, Department of Geology and Geophysics, Yale University.
- Farrington, O.C.
 1915. Catalogue of the Meteorites of North America. *Memoirs of the National Academy of Sciences*, 13: 513 pages, 36 plates.
- Graham, A.L., A.W.R. Bevan, and R. Hutchison
 1985. *Catalogue of Meteorites*. Fourth edition, 460 pages. London: British Museum (Natural History).
- Haidinger, W.K.
 1860. Einige neuere Nachrichten über Meteoriten, namentlich die von Bokkeveld, New-Concord, Trenzano, die Meteoreisen von Nebraska, vom Brazos, von Oregon. *Sitzungsberichte der Akademie der Wissenschaften*, Wien, 41:568-572.
 1861. Meteoreisen von Rogue River Mountain in Oregon und von Taos in Mexico, gesandt von Herrn Dr. Charles T. Jackson. *Sitzungsberichte der Akademie der Wissenschaften*, Wien, 44(2):29-30.
- Henderson, E.P., and H.M. Dole
 1964. The Port Orford Meteorite. *The Ore Bin*, 26:113-130.
- Hey, Max H.
 1966. *Catalogue of Meteorites*. Third edition, 637 pages. London: The British Museum (Natural History).
- Huss, Gary R.
 1990. Meteorite Infall as a Function of Mass: Implications for the Accumulation of Meteorites on Antarctic Ice. *Meteoritics*, 25:41-56.
- Jackson, Charles T.
 1860. [Minutes of meetings on several dates in late 1859.] *Proceedings of the Boston Society of Natural History*, 7:161, 174, 175-176, 279, 289.
 1861. A Sketch of the Life and Scientific Services of John Evans, M.D., U.S. Geologist for Oregon and Washington Territories, and of the U.S. Chiriqui Exploring Expedition. *American Journal of Science*, 32:311-318.
- Lange, Erwin F.
 1959. Dr. John Evans, U.S. Geologist to the Oregon and Washington Territories. *Proceedings of the American Philosophical Society*, 103:476-484.
- Marvin, U.B.
 1989. Meteorite Distribution at the Allan Hills Main Icefield and the Pairing Problem. In U.B. Marvin and G.J. MacPherson, editors, Field and Laboratory Investigations of Meteorites from Victoria Land and the Thiel Mountains Region, Antarctica. *Smithsonian Contributions to the Earth Sciences*, 28:113-119.
- Mason, Brian
 1963. The Pallasites. *American Museum Novitates*, 2163, 18 pages.
 1975. Mineral Sciences in the Smithsonian Institution. In G.S. Switzer, editor, Mineral Science Investigations 1972-1973. *Smithsonian Contributions to the Earth Sciences*, 14:1-10.
- Merrill, G.P.
 1916. The Shepard Collection. In Handbook and Descriptive Catalogue of the Meteorite Collection in the United States National Museum. *United States National Museum Bulletin*, 94:175-199, plates 37-40.
- Pellas, P., C. Perron, G. Crozaz, V.P. Perelygin, and S.G. Stetsenko
 1983. Fission Track Age and Cooling Rate of the Marjalahti Pallasite. *Earth and Planetary Science Letters*, 64:319-326.
- Plotkin, Howard
 1992. John Evans and the Port Orford Meteorite Hoax. In Roy S. Clarke, Jr., editor, The Port Orford, Oregon, Meteorite Mystery. *Smithsonian Contributions to the Earth Sciences*, 31:1-24.
- Post, J.E., and V.F. Buchwald
 1991. Crystal Structure Refinement of Akaganéite. *American Mineralogist*, 76:272-277.
- Saikumar, V., and J.I. Goldstein
 1988. An Evaluation of the Methods to Determine the Cooling Rates of Iron Meteorites. *Geochimica et Cosmochimica Acta*, 52:715-726.
- Scott, E.R.D.
 1977. Pallasites—Metal Composition, Classification and Relationships with Iron Meteorites. *Geochimica et Cosmochimica Acta*, 41:349-360.
 1989. Pairing of Meteorites from Victoria Land and the Thiel Mountains, Antarctica. In U.B. Marvin and G.J. MacPherson, editors, Field and Laboratory Investigations of Meteorites from Victoria Land and the Thiel Mountains Region, Antarctica. *Smithsonian Contributions to the Earth Sciences*, 28:103-111.

Scott, E.R.D., and J.T. Wasson

1975. Classification and Properties of Iron Meteorites. *Reviews of Geophysics and Space Physics*, 13:527-546.

Sedell, Ellen C.

1968. The Lost Port Orford Meteorite. *Oregon Historical Quarterly*, 69:29-49.

Ward, H.A.

1906. Three New Chilian Meteorites. *Proceedings of the Rochester*

Academy of Science, 4:225-231, plates 23-25.

Wülfing, E.A.

1897. *Die Meteoriten in Sammlungen und Ihre Literatur*. 460 pages. Tübingen: Verlag Der H. Laupp'schen Buchhandlung.

Zolensky, M.E., G.L. Wells, and H.M. Rendell

1990. The Accumulation Rate of Meteoritic Falls at the Earth's Surface: The View From Roosevelt County, New Mexico. *Meteoritics*, 25:11-17.