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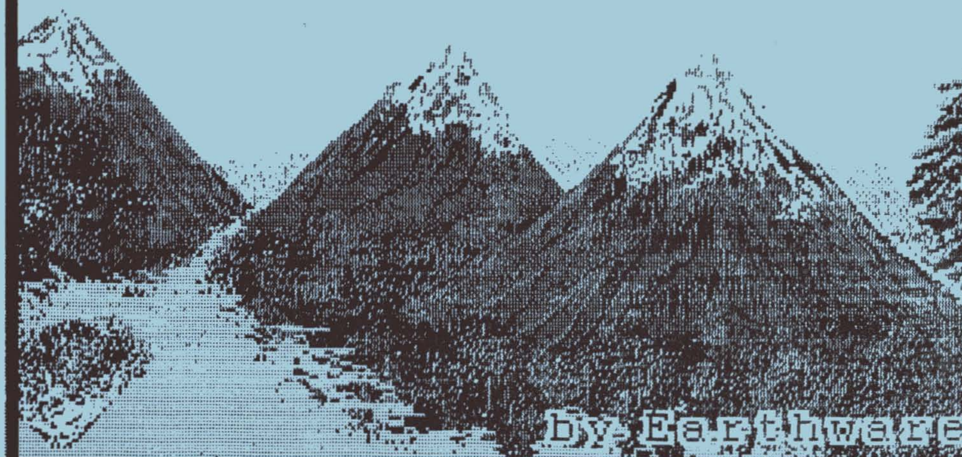
Volcanoes®

and

Volcanoes Deluxe Handbook



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Volcanoes®

and

Volcanoes® Deluxe

Handbook

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Getting Started: General Information for All Users of *Volcanoes®*

You can play *Volcanoes®* without reading any of the documentation because the instructions are all printed on the screen. However, it is important that you know what the various investigations do so that you may interpret the data correctly.

Wrangelia is a mythical land, the existance of which is still being debated among scientists. The positioning of the various types of volcanoes in close proximity is contrary to nature and is attributed to *artistic license* used to create a game playable on the computer screen.

Volcanoes® uses a game format to teach diverse attitudes and skills and to present a great deal of information. Being professional educators, we recognize that you may view this as an unusual approach to teaching. The advantages of this format include improved student motivation and better retention of material. Among its disadvantages is that you may need extra time to prepare the material based upon your use of the program. This manual is intended to help you reduce the time needed to spend preparing to use *Volcanoes®*, and incorporates suggestions for effective use of the program.

One turn in the game is equivalent to three months in the "real" world. We suggest that you play a given game for no longer than two hours. Children in the sixth grade through adult can benefit from using the program.

You will need to know some basic vocabulary to utilize this game. *Volcanoes®* is designed to encourage thinking and to teach concepts essential to understanding the volcanic process and the mechanisms used to predict eruptions.

The new deluxe versions for the PC compatibles and the Apple IIGS begin in the year 2000 while the old Apple II versions begin in 1980.

Permissions Granted Original Purchasers:

Permission to reproduce the copyrighted materials is granted to the original purchaser only for use in his/her classes. The right to distribute the program is limited to Earthware® and persons authorized by Earthware®. This means that no teacher shall make copies for distribution to other schools thoughout a school district. A back-up diskette may be made for the purpose of archiving. Maps and copies of information about the investigations may also be reproduced. Permission is also granted to print any of the pictures on the disk for classroom use and study if you have a version with the print function.

Additional disks are available at $10* each through your dealer or Earthware. Special configurations are possible through Earthware. Lab packs may be ordered through dealers, distributors or Earthware. [*prices subject to change without notice]

Using the Maps:

The maps are designed to allow for 1, 2, 3, or 4 players. If only one person is playing, he/she gets to supervise the entire territory. If two are playing, then the first player will need maps 1 and 2 and the second player 3 and 4. If three are playing then maps one, four, and five will be utilized. This program can work very well for an entire class in teams or with individuals.

You will find that you have two copies of each map that have numbers one through five. The maps have "x" and "y" coordinates marked on them. As you play the game and do the investigations, you will gain valuable information about the volcanoes in your area. This information should be recorded as you play the game to determine which volcanoes are the most likely to erupt.

The maps have coordinates that begin at "0" in the lower left hand corner and increase as you move toward the right.* You probably know how to locate a point on the map using the "x" and "y" coordinates. You will recall that the "x" axis runs horizontally and the "y" vertically. [*slightly less clear with old Apple II version.]

Regarding Budgets and Creditabilities:

Volcanoes® is designed so that you may change the warning levels for areas other than your own BUT if you set the warning levels of other players recklessly, the creditabilities of all players decrease but in varying degrees. Good predictions can reduce damages or lives lost in eruptions by giving timely warning, and increase the creditabilities of all players, in particular the player in charge of the area in which the eruption occured and who made the accurate prediction.

Budgets depend upon both public and scientific creditabilities as well as the tax base of the areas for which you are responsible. Tax bases generally grow with time but are diminished by damaging eruptions so it is important to make good predictions. [i.e. In real life if a large building is destroyed by fire, it cannot be used as office space until it is rebuilt. While it is unusable, taxes on that property are diminished.] In the game of life, one must cooperate to understand natural phenomena and to limit the damaging effects of dangerous natural processes. *Volcanoes®* contains elements of competitiveness but these are less prominent than in other strategy games.

Getting Started Using the PC or Compatibles:

Hardware configuration for either the I.B.M. PC® or compatibles is 256K of memory, color monitor and one or two floppy disk drives, 5.25 inches. You will need the Microsoft® DOS, version 2.0 or later.

To boot the program simply insert the System Master disk in drive "A". When the disk in "A" stops running, replace that disk with your Volcanoes disk and type "Volcano". This program may be used with a one or a two drive system. The latter is preferable because if you boot with the first drive, insert the *Volcanoes®* disk in "A" and a formatted disk in "B", you will be all ready to save your game when the time comes.

Now that the title screen is up you will be asked to enter the name of the volcanologist who is in charge of Afringham, etc. Prior to booting the game, decide who your team leaders are and gather all necessary materials so that valuable time will not be lost. Map grids are only on the printed sheets which accompany the game. If you lose them, you must get additional copies from Earthware.

Saving Games with PC Compatibles:

There is very little room for saving games on the program disk and therefore it is best to have a formatted blank diskette ready to use for saving your games. You should use the same disk every time and update the game by saving it using the same name or add new games by changing the name. You may exit and save a game at the end of a season only. Therefore, you must watch your time if you are using the game in a classroom situation. You might select "No" when asked whether you wish to continue playing if time is getting short and save the game. You may then re-enter the saved game and play until time is up. Simply select "exit", type the name of your game, and press return to save your game.

The PC version is a more graphic program than the old version and it is not copy protected. Among the enhancements, you have an **Information Screen** that is intended to give you an idea of the layering of the earth as scientists currently believe it to be configured.

****

Logging On and Beginning Play Using the Apple

IIGS.

Before you can play you should have the following hardware configuration: Apple IIGs with at least 512K expansion RAM, one or two 3.5 unidisk drives, RGB monitor, and mouse. The play is enhanced with a megabyte of memory because pictures that must be reloaded from disk, become memory resident, thus speeding up the game.

Loading Instructions for the GS Version of Volcanoes® Deluxe....

...with one disk drive (3.5)
Place your ProDOS 16 version 3.1 or newer disk in the first drive. When the drive light goes out, remove the disk and insert your Volcanoes disk. Select, Volcanoes.sys16 from either the Program Launcher or from the Desktop.

...with two disk drives (3.5)...
Place your ProDOS 16 version 3.1 or newer disk in the first drive, the one that runs first when you turn on the computer. When the light goes out, remove the disk an insert your *Volcanoes®* disk. Now follow the same procedure as listed above for use with one drive.

Logging on is simple because all of the areas are in need of a volcanologist. You will learn a bit about the area before you decide to work in any particular area. At this time you should have maps with grids of your particular area. As mentioned before, the grid does not appear anywhere else except on the printed maps.

Sequence of Play on the GS:

Volcanoes® uses the Desktop environment. Select "New Game" from under "File". At this point you will be asked to decide the level of difficulty and tell the computer how many are playing. Then, you will be asked to enter your name. After you enter your name(s) as scientist(s) for an area, the screen will turn a pretty hue--and remain very blank until you select the player who is to go first. Then, select an investigation from under studies. Continue selecting studies until you have tried all of them or exhausted your curiosity (or budget) with regard to your volcanoes. Set warning levels for your volcano and turn over the reins of power to another scientist by selecting another name under player. Remember your creditability depends upon accurate predictions!

The advantage of the game in this format is that you may decide on the basis on one investigation to change warning levels for an area and be able to do that at once rather than at the end of your turn. In addition, players may go in whatever order they wish owing to the GS format.

Saving the Game and Deleting Files on the GS and the Apple II

Using the GS, you may select "Save" at any time and exit the program. If you have investigations that are on the screen with the windows open at the time that you decide to go to "File" and select "Save", that information will NOT be saved.

Investigations with results to be given "Next

Season" will be saved. Therefore, if you are in the middle of a Gas Analysis, you must decide to either finish the investigation or to abort and re-do it next session. In the latter case, you have already been charged for the investigation and so it would be best to finish it. (It is a "Cash in advance" type of situation--an experience consistant with the "real world".)

The **Apple II** save routine is complex owing to disk space and file accessibility. The history of vulcanism is on the front of the disk and the game is on the back. Each time you save a game both of those files are created or updated. (Disk frontside files contain the prefix "H." and backside files "G.") You should have an instruction sheet for the Apple II series "delete game" function. If you do not, please request it from us, it is *vital* information. Use no write-protect tabs on this version!

Printing Pictures Using the GS:

The pictures on the disk may be printed using an Imagewriter II printer if you have the GS version. You select "Print" which is under "File" and you will be asked which pictures you wish to print. Pictures may be printed in color if you have a color ribbon.

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Volcanoes® Deluxe--Menu Descriptions for the GS

Menu functions for the GS* version are discussed below for your convience. You may choose to photocopy these for classroom use, if you are using this program in that situation.

File:

New: Use this to start a new game.

Load: Loads an old game that was saved on disk.

Save: Saves the current game.

Close All: Closes all of the windows visable.

Print: Prints the eruption pictures, the map of Wrangelia, Earth's crust, and a current history of eruptions.

Quit: Quits the game.

Edit: This menu option is not used by this program.

Studies: These are the various investigations which are performed on the volcanoes. Detailed information is to be found in the "Investigation" section of this manual. *Notice* that some of the machines will not function if you do not remember to turn them on!

Players: This option enables users to select order of players to conduct the investigations, set warning levels, or go to next season.

Options:

<u>History</u>: Read about the recent history of volcanism with the micro fiche viewer.

<u>Earth's Crust</u>: View the earth's crust in a colorful cut-away view.

<u>Wrangelia</u>: Shows the map of Wrangelia.

<u>Warnings</u>: Set the warning level for the inhabitants of your area(s).

General Historical Background

Almirante Perulera, commanding a squadron of three ships and ordered by the Spanish government to search for a Northwest Passage, first sighted several of the volcanoes of the Wrangelia region in August of 1786. He named Mt. Asuncion, Boca Cerrada Peak, and Mt. Fuego (which was erupting when first sighted) of the archipelago now named for Captain Atringham of H.M.S. Astrolabe, who made landfall there in July 1788. Perulera also named El Matador on the mainland, from a fancied resemblence of that cinder cone and the shield volcano of Rift Mountain (originally named El Toro) to a bullfighter and bull. He (or rather, his lookouts; the Almirante is thought to have been near-sighted) must have seen many other volcanic edifices of the region, but there is no mention of them in the expedition's logbooks preserved in archives at Barcelona.

Perulera's ships anchored just outside Dog Leg Harbour, between George Island and Charlotte Island to take on water, firewood, and whatever food could be obtained (chiefly smoked salmon and dried berries, according to logbook entries) by trade with the local inhabitants.

From later writings by Sir Eduardo Churruca, aboard as a volunteer (?) naturalist, it is clear that at least one small party from the ships climbed the northern slopes of Mt. Fuego to the rim of the summit caldera, and observed fire fountains and lava flows erupting from the South Rift Zone. Churruca describes how the tongues of lava divided as they flowed around the base of what we now know as Rolling Stone Butte; his description allows us to identify confidently the products of the 1786 eruption, even though Mt. Fuego has erupted quite frequently since then.

The Perulera expedition put out to sea rather hurriedly, apparently because they were alarmed by signs of an impending eruption of Mt. Asuncion. The logbook does not state clearly where the alarming symptoms originated, but because Perulera's ships had not fully replenished their essential stores, it seems likely that the volcano showing signs of activity was thought to be potentially more dangerous than was Mt. Fuego. Perulera did not discover the splendid anchorage of Georgeville Harbour, and certainly his ships would have been seriously threatened by even a moderate eruption of the Asuncion volcano, if the wind had shifted towards a more northerly bearing.

When Afringham sighted the archipelago that now bears his name, not quite two years later, Mt. Fuego was quiet but Asuncion was emitting minor steam bursts and ash-laden blasts, and a very fresh-looking lava flow exhibiting an alignment of steam vents, apparently where it had overriden a small stream valley (forming lahars), was seen on Asumcion's southeastern slopes. Although Afringham commented at some length on this spectacle in his logbook, no such flow was mentioned by Perulera, but the omission may not be significant. On the whole, it seems likely that Asuncion did indeed erupt a lava flow between August of 1786 and July of 1788; this lava seems to have been buried by products of more-recent eruptions of the volcano.

Afringham found and was much taken with Georgeville Harbour, although his enthusiasm for it was somewhat tempered by the light shower of volcanic ash from Mt. Ashfall (named by Aftingham in honour of the occasion) that was carried by an east wind to sprinkle the rigging and deck of his ship during 21st to 23rd of July, 1788. (This wind direction is unusual; west winds prevail in Wrangelia during most of the year.) Afringham recognized the protential hazards of eruptions from Asuncion and Ashfall, but seems to have been unaware that Georgeville Harbour itself was formed by lavas from the Deadfall Butte cinder cone, and could in some future eruption be closed off by such a lava flow. His report emphasized the advantages of the harborage and the abundance of natural resources such as fish, furs, and timber far more than the volcanic hazards, and was instrumental in encouraging the first European settlement, at Georgeville in 1801.

Although many ships visited the archipelago and the coastal areas of the adjacent mainland during the early 1800's, and there were permanent European settlements at Georgeville and Camas Marsh (later re-named Camasport), we have regrettably-little information about volcanic activity during the first part of the nineteenth century, perhaps because it was so common as to be unremarkable. We know of an eruption of wide-spread air-fall ash from Boca Cerrada during the winter of 1815, and there are somewhat-confusing reports of what probably was an ash-flow tuff (ignimbrite) erupted from Cumulus Peak that destroyed good fur-trapping grounds northwest of that volcano during the summer of 1823.

Reconnaissance geologic mapping of coastal Brigalorn suggests that a tongue of this ash flow may have moved down the Talogit River valley nearly to the present site of Talogit City. Precise date of the eruption of this ignimbrite has not been determined.

Until the 1860's, the areas east of the Cumulus Peak--Skyline Peak--Mt. Ashfall axis were very sparsely settled. Beginning in that decade transcontinental migration and the growth of agricultural settlements along the rivers of interior Derkin changed that general area from a largely-ignored hinterland to one of considerable economic importance. This process was greatly accelerated by discovery of placer gold deposits east of the city of Salmon Creek, which grew rapidly as a consequence. Salmon Creek now is a mining, lumbering, and manufacturing center rivalling the older communities of Georgeville (fishing, textiles, manufacturing, and shipping) and Camasport (manufacturing, shipbuilding, and shipping wood products, electronics).

Four smaller cities are located in the region. Arbol Creek, at the south end of Prince Ernest Island, depends on fishing, papermills, and lumber. Talogit City, across Afringham Passage to the east of Arbol Creek, ships food products, building stone, and lumber. Wolfridge at the confluence of Thunder River and the South Fork of Camas River, about 35 kilometers NE of Cumulus Peak, is known for forest products, tourism, a major wildlife park, and outdoor recreation. Indian Ford on the north bank of the main stem of Camas River, about 40 kilometres SW of Mt. Ashfall, specializes in manufacturing, food

processing, and dairy products and their distribution, and is a transportation hub.

The small towns in Afringham are Dog Leg Harbour and Driftwood (Charlotte Island) and Emily (Prince Ernest Island). Ratchetville is located in coastal Brigalorn, just west of Ratchet Mountain, and Deertrail is in interior Brigalorn, about 34 kilometres east of Cumulus Peak. In Camasport (the name of both one of the principal cities of Wrangelia and of the province in which that city is located), Black Sand Beach is on the coast, just north of the Rift Mountain shield volcano, and Slide is about 28 kilometres east of the city of Camasport. Small towns of Derkin are Otter Rock and Seal City (south and north, respectively, of the Derkin River in coastal Derkin) and Greentree, along the upper Camas River, about 40 kilometres SW of Salmon Creek.

Volcanology

The major volcanoes of Wrangelia have been classified, somewhat arbitrarily, into three types: andesitic composite volcanoes, basaltic shield volcanoes, and cinder cones. The five andesitic volcanoes are much like those found at and near continental margins around the Pacific, except they seem to erupt more frequently than is commonly observed elsewhere. Reconnaissance studies have shown that they tend to erupt pyroclastic materials (air-fall ash tuff blankets and ash-flow tuffs) more frequently than lavas, although this conclusion may be wrong because the lavas tend to be restricted to the slopes of the volcanoes, and the tuffs are typically widespread. These volcanoes are called "composite" because they are composed of nearly equal amounts of lavas and of fragmental materials like tuffs and lahars, but of course we do not know, even roughly, what the proportions of these eruption products are in any composite cone because the youngest materials veneer and hide the older ones, and all the cones have been eroded only to a minor degree.

Three basaltic shield volcanoes (one in the Afringham archipelago--for which a better term might be the "Afringham island arc"--and two that are part of the mainland coastal belt of volcanic vents) in the region erupt frequently, sometimes from rift zones that cut these volcanic edifices, sometimes from the summit caldera found in each. Eruptions from vents at or near the summit tend to precede those from rift zones, much as has been very well-documented for Hawaiian shield volcanoes in their youthful stages of development. Fire fountaining is common, especially

during early stages of summit eruptions, and often spectacular but rarely hazardous. Lavas, especially those erupted from rift zones low on the flanks of the shields, tend to cause most of the damage and the rare injuries associated with this style of volcanism.

Although the andesitic composite cones and the basaltic shield volcanoes of this region are in many ways quite similar to their counterparts elsewhere, some at least of the cinder cones of this region appear to be unusual. In general, it is rare to observe multiple eruptions, separated by quiescent periods of many years, from cinder cones. They tend, rather, to erupt during a fairly short time-span, building the entire edifice (a cinder cone, sometimes with a lava flow breaking out of its base late in the eruptive cycle) and then becoming extinct. Fragmentary evidence (e.g., see outlines of eruption histories for Deadfall Butte, Moss Mountain, and Rolling Stone Butte) suggests that at least some of the cinder cones of this region have erupted repeatedly. It is probably prudent to consider all of them as dormant unless detailed studies of individual cinder cones suggest that they are indeed extinct. Perhaps some of the region's cinder cones are in reality very youthful composite volcanoes, that simply have not yet grown to sizes that would make it easy for us to recognize them as such.

Volcanic eruptions in the region since 1875 have been reasonably well-documented; summaries of the historic records of these eruptions, 1875 to 2000 are given below, following tabulations that will help you to keep in mind the names and locations of the volcanoes.

Summaries of Records of Volcanic Eruptions (pre-2000)

Mt. Asuncion--probably erupted a lava flow during the period 1786 to 1788.

--Between about 1790 and 1820 it erupted four ignimbrites and at least six air-fall ash tuffs.

--It may have erupted a lava flow in 1833; it erupted a large air-fall ash, accompanied by a lahar which caused 98 deaths and much damage in Georgeville, during 1872.

--An ignimbrite eruption which caused minor damage to forests occured in 1833 but apparently has been dormant from 1892 to 1980.

--In 1981 the alledgedly "dead" volcano came to life and erupted a large ash-fall tuff and a lahar. This eruption caused the deaths of 1180 people and much damage in Georgeville.

--1989 the volcano erupted a small ignimbrite which resulted in little damage to the surrounding countryside which had not yet recovered from the great eruption of 1981.

--in 1993-6 steam was seen coming from the main vent but since then the volcano has been quiet.

Boca Gerrada Peak--erupted extensive air-fall ash in 1813, and again in 1882, 1902, and 1913.

--Ignimbrites were erupted in 1893, 1901, and 1913. There were minor eruptions from 1913 to 1930.

--dormant from 1930 to 1960.

--Smoke and steam preceeded a small eruption in 1963 but there has been no activity since then.

Gumulus Peak--The eruption activity of this volcano is poorly documented; --probable eruption of an ignimbrite in 1823.

--Air-fall ash erupted in 1929, 1933, 1948, 1953, and 1958. In the last eruption six lives were lost as there were prospectors in the area at the time of the eruption.

--Ignimbrite eruption in 1943.

--Dormant from 1958 to present.

Skyline Peak's eruptive history is poorly known; as long ago as 1875, eruptions from it and from nearby cinder cones have not been reliably distinguished.

--It may have erupted as many as ten times between 1800 and 1875.

--It erupted an ignimbrite in 1884, with heavy damage to forests northeast of the peak.

--It appears to have been dormant until the present time.

Mt. Ashfall--was named after a large euption in 1788. At least thirteen eruptions of ash, the dates of which are poorly known, were seen from Georgeville between 1805 and 1875; additional eruptions are recorded for 1803, 1821, 1828, 1838, and 1845.

--The history of eruptions of ignimbrites, lahars, and lavas is unknown. It has been dormant from 1845 to 2000.

Mt. Fuego erupted lava and vent agglomerate (from a remarkable fire fountain) in 1786, and at least five lavas between then and 1880.

--Known lava eruptions occured in 1903, 1909, 1915, 1919, 1928, 1933, 1934, 1938, 1941, 1961, 1962, 1963, 1982, 1985, 1989 and 1993. No eruptions have occured since 1993.

Rift Mountain--erupted lava at least three or four times between 1832 and 1860.

-- Lava erupted in 1885, 1887, 1895, 1914, 1925, 1929, 1930, 1931, 1943, 1944, 1950, 1952, 1955, 1964, 1965, 1981, 1982, 1983, 1990 and 1994 and 1995.

--No eruptions since 1995.

Flat Top Mountain--experienced fifteen lava eruptions between 1804 (when lava was seen at the the Western Rift Zone) and 1813 were observed from Georgeville, but except for the 1804 and the 1802 events, exact dates are not known.

--Eruptions from the Eastern Rift Zone prior to 1940 may have gone unnoticed. Lava erupted in 1917, 1920, 1945, 1955, 1960, and 1878.

--Dormant from 1878 to 2000.

Deadfall Butte--erupted air-fall ash in 1803, 1813, 1816, 1821 (seven lives lost, many injured), 1823, 1891, 1984, 1930, 1931, and 1936.

-- It erupted lava in 1818, 1824, 1883, 1886, 1933, 1935, 1937, 1945, 1947, 1950, 1955, 1960, 1963, 1967, 1969 and 1971.

--It has been dormant from 1971 to 2000.

Rolling Stone Butte--like its neighbor, Moss Mountain, is hidden from the Georgeville area by Mt. Fuego, and often hidden from Oamasport by persistent fog in Afringham Passage.

--Many eruptions prior to 1945 may have gone unnoticed.

--Ash erupted in 1833 and again in 1942; a series of eight ash eruptions, terminated by a lava flow, occurred during the period 1972 to 1992 and was studied with some care.

--Dormant from 1992 to 2000.

Moss Mountain--Like Rolling Stone, Moss is difficult to observe and many eruptions prior to 1945 may have gone unnoticed. Lava flows erupted in 1925 and 1962; air-fall ash in 1958, 1959, 1964, 1966, 1967, 1973.

--Dormant from 1973 until the present year of 2000.

Dogwood Mountain--is named after a common tree in the forest dominating it. No record of eruptions is known.

Ratchet Mountain--despite its location in a zone of heavy rainfall, is lightly vegetated and may therefore have erupted vigorously within the past few hundreds of years. --No known eruptions.

Rumble Butte--is moderately well-vegetated; no known eruptions.

Bear Claw Butte--is heavily forested, except on the surfaces of a relatively recent lava flow that issued from the northeast part of its base. --No known eruptions

Salt Lick Mountain--sits on metamorphic rocks and relatively old sedimentary rocks; it is lightly vegetated, but has no history of known eruptions.

Broken Thumb Butte--erupted lava in 1822 and air-fall ash in 1818 and 1825.

--Minor steam blasts were observed in 1862, 1863, 1885, and 1986. Dormant from 1886 to the present.

El Matador--is heavily vegetated and presumably has not erupted for at least several hundred years.

Bubbling Springs Mountain--hot springs beneath the mountain for which it is named.

--it is lightly vegetated and may have erupted during the period 1887 to 1811.

Broken Fish Mountain--must have erupted at least two air-fall ash blankets and one lava flow since 1873 when it was described in a trapper's journal. The dates of these eruptions are not known.

--It has been dormant from 1823 to the present.

Forked Tongue Butte--is named after the 'forked' lava flow that issued from its base on the NW side. This lava covers ash that is probably from the eruption of Mt.

Ashfall eruption of 1788, but could be younger. It is itself overlain by three distinguishable air-fall layers, from unknown sources.

--Dormant from at least 1929 until present.

Dyke Butte--is named after two sets of prominent radiating dikes, exposed by erosion on its N and NE sides. Apparently dormant for hundreds of years.

Conejo Mountain--consists of twin peaks, thought to resemble rabbit ears and joined by a saddle of moderate elevation.

--Conejo is a large edifice with some vegetation and no history of eruptions.

Twisted Trunk Mountain--stands at a relatively high elevation, where regrowth of plant cover after eruptions is slow, yet it seems to be about as well vegetated as are neighboring areas. No known eruptions.

Whisper Butte--is a large cinder cone covered by a pine forest with no history of eruptions.

The Investigations

History of Volcanic Eruptions (after 2000):

Your computer keeps track of all volcanic eruptions reported in Wrangelia after 2000. (For information on what is known about eruptions before 2000, at the time you took up your research position, see the Summaries section above). You can call up those records, to remind yourself and your colleagues about which volcanoes have been active recently, and how dangerous they have been. A shield volcano that has erupted recently is moderately likely to erupt again in the near future. There may be either a series of closely-timed eruptions from the other kinds of volcanoes, or one or two eruptions followed by long periods quiescence.

Infrared Scan of an Area:

The purpose of this investigation is to find "hot spots" in an area that may indicate volcanic hazards.

Background: If magma has been stored in a shallow chamber for a few years or more, the heat flowing from the magma into the surrounding rock can act to raise the temperatures of the rocks and soils at the Earth's surface near the magma chamber. These elevated temperatures can be detected by a variety of types of measurements (placing your hand on the ground to test if it feels warm is NOT one of them!). However, you should note that if a magma chamber is deep, or small, or young, or if lots of groundwater is flowing over the top of it and carries away its heat, it might not be detected even by a

very careful survey of surface temperatures. Also, human activities of many different kinds produce heat, and if you are not careful about your interpretations you could mis-identify "hot spots" that result from human activities as signatures of magma chambers.

Method: space satellites that are instrumented to survey earth resources, and specifically to examine the Earth's surface in infrared light (the wavelengths of light that are longer than those we can detect with our eyes, and are profusely emitted by warm or hot objects), pass over Wrangelia and are available for your use. However, the sensors on those satellites are not well-suited to penetrate cloud cover, which is very common in western Wrangelia during the winter and parts of the autumn and spring. An alternative is to use infrared sensors mounted on airplanes, if the satellite images are not available (or just to wait for the weather to clear). In either case, the data on intensities of infrared light that were recorded by the instruments you chose to use will be "massaged" by a computer, and the locations of "hot spots", if any are found, will be reported to you. You must then interpret that information.

Seismic Survey of a Volcano:

The aim of this investigation is to look for volcanic tremor or other evidence of impending volcanic activity.

Background: Seismic signals are waves travelling through the Earth that are produced by natural events. They include but are not limited to waves from earthquakes. A particular kind of seismic signal that is important in studying volcanoes is "volcanic tremor", the fairly-regular vibrations caused by magma moving through volcanic "plumbing systems". (In a sense, volcanoes often hum to themselves when they are pumping their working fluid --magma--from one place to another. The humming is in some ways similar to tones produced by a wind instrument, such as an organ or a flute, although of course the working fluid--air in one case, molten rock in the other--is very different.) Movement of magma within a volcano precedes almost all eruptions, although magma can move and then simply stay within the volcano, rather than erupting.

Local seisms, usually caused by small earthquakes within or near the volcanic edifice, also can be symptoms of internal readjustments that may precede eruptions. In typical local seisms, a burst of energy signals the arrival of the seismic waves at the seismometer, and the intensity of the waves then dies away fairly smoothly. This is because, although there are different kinds of seismic waves that travel at different velocities, when they are generated close to the seismometer that detects them, the waves have not traveled far enough to sort themselves out according to their velocities. In volcanic regions, most local seisms are too weak to be detected at any substantial distance from their sources, so that if your seismometers record local seisms, you can be fairly certain that they originated in or near the particular volcano you are studying. Teleseisms (those that have travelled a long way) will show a pair of distinct first arrivals, initially of the "primary wave" (which travels faster), then of the "secondary wave". They are likely to appear in

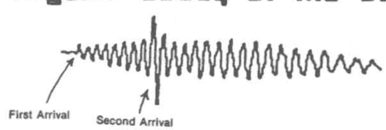
your seismic records, but do not help you to predict volcanic activity in your areas.

__Method__: You have available to you a number of seismometers that can be set up to operate remotely, recording seismic events and telemetering by radio their records when they are directed to do so by a central data-processing installation. They are relatively light-weight (no seismometer is really "light-weight", because the part of it that actually records wave motion must be massive enough to resist moving easily, through its inertia, when the ground begins trembling under it), and can be set up almost anywhere on the slopes of a volcano. The computer that processes the data will report to you the average number of seismic events with intensities (Richter magnitudes) greater than three recorded per month, and will show you a selection of typical seismic records for you to examine and interpret. Note that if you choose to put lots of seismometers on a particular volcano, you will almost certainly detect more events than if you had put fewer instruments in the field. Thus, the number of fairly-energetic events, although it is partly dependent on the internal state of the volcano, is also partly dependent on the way you did this investigation. The presence or absence of volcanic tremor, or of local seisms, among the events observed should be a useful guide to the chances of an eruption from that volcano occurring in the near future, although as noted above, magma can be moving around within a volcano and the volcano can be generating local seisms, but never erupt. Use your judgement.

Below are some illustrations of the various seismic signals that you can expect to receive when using *Volcanoes*

This is an example of a local seism.

Note the sharp and intense beginning of the seismic wave form, the lack of a second arrival, and the fairly regular decay of the wave form.



This is an example of a teleseism (one that originated at a great distance from the seismograph). Note the distinct first and second arrivals, of the primary ('push-pull') and secondary waves, respectively. The secondary waves appear as sideways waves as in a rope that is supported at one end. Note also that the wave form dies away slowly, because of the way energy is spread out within the earth.

This is an example of volcanic (or harmonic) tremor, the kind of seismic signal that volcanoes produce when magma is moving within their 'plumbing systems'. Note the abrupt beginning and end of the wave form, and its very regular character, with little change in either intensity or frequency.

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Map of Wrangelia

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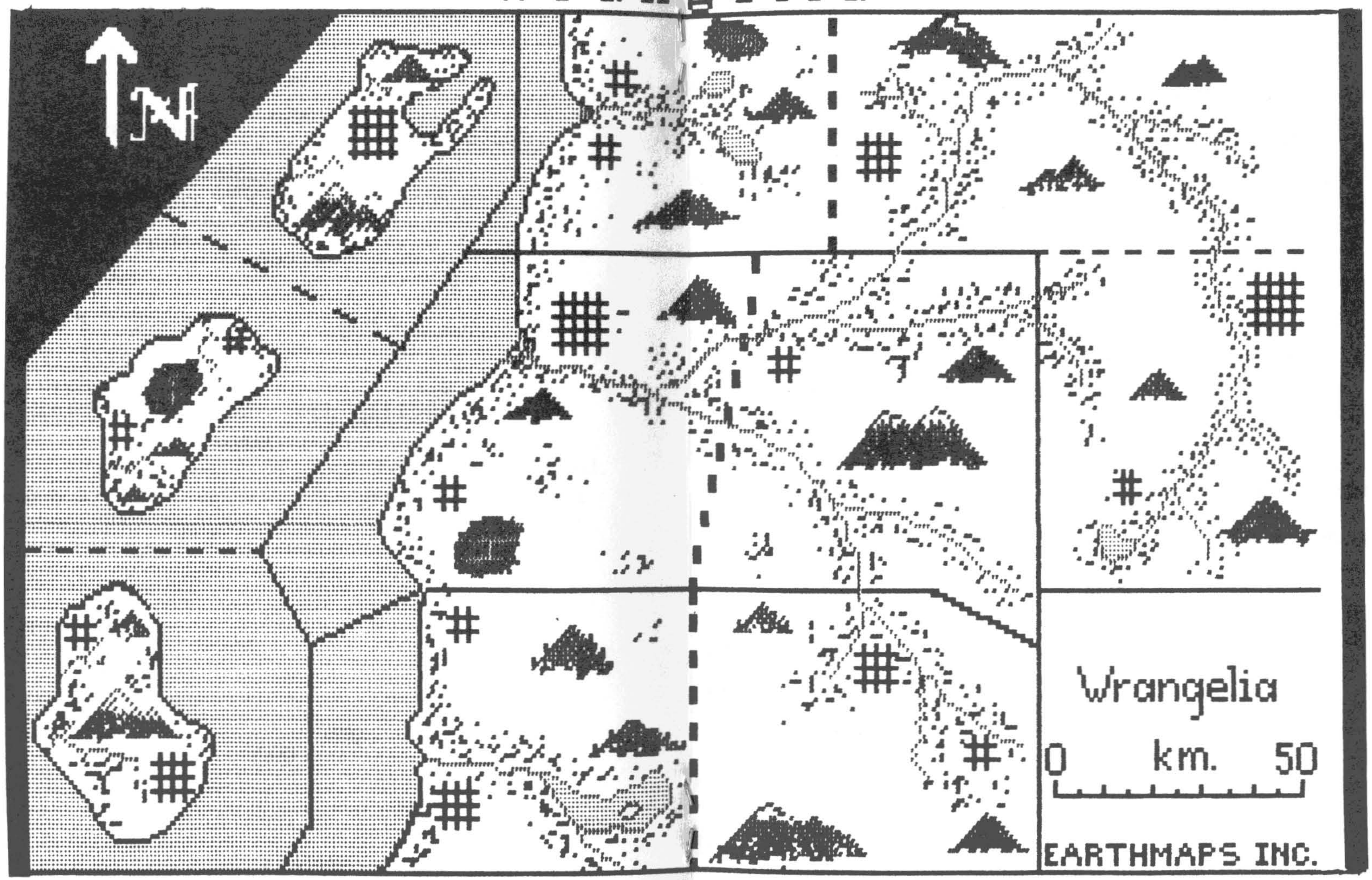
Wrangelia



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Map of Wrangelia

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Electrical Conductivity Near a Volcano:

The purpose of this investigation is to detect zones of unusual electrical conductivity, which may indicate the existence of shallow magma chambers.

Background: Most rocks are good electrical insulators (or poor electrical conductors, which is just another way of saying the same thing). However, there are some earth materials that exhibit unusually large conductivities. They include: 1) ore minerals of many kinds, and 2) magma (which conducts electricity far better than do common rocks). Thus, if one can measure electrical conductivity on a broad scale, it becomes possible to search for either economically-minable ore bodies or for shallow magma chambers. It is difficult to find deep magma chambers with this kind of survey, because the conductivity anomalies they cause tend to merge into anomalies formed in other ways, but if (as is the case for most of Wrangelia) you can be fairly sure that ore bodies are not common enough in the area surveyed to confuse the picture, it is a good approach to detecting shallow magma chambers.

Method: One of the most useful methods of determining electrical conductivity on an appropriate scale is to lay out a loop of thick electrical cable, put an electrical pulse through it which generates a strong magnetic pulse, and observe in detail how that magnetic pulse interacts with the Earth. Field magnetometers are fairly inexpensive and easy to carry around, and it is best to set up the loop and the electrical generator (usually truck-mounted) in one location near the center of the area you want to survey, then to move the magnetometers around.

The truck is stopped at a number of locations and records the results of transmitting a series of magnetic pulses. A small computer is usually set up in the truck, along with the rest of the equipment that is required, and "chews" on the data as they are radioed in from each of the magnetometer stations in turn.

With this approach, your survey team can build up a model of the electrical conductivity anomalies as they are working. When they decide they have been away from town long enough, and have ample data to impress you with what a good a job they have done, they can pull stakes (really, pick up the big loop of wire).

You will get a report of where conductivity anomalies have been found. You must then interpret those anomalies or their absence. Keep in mind that not every volcano with a shallow magma chamber will erupt in the near future, and that volcanoes may erupt by drawing magma from deep sources, that you cannot detect with this kind of investigation.

Tiltmeter survey of a Volcano:

The purpose of this investigation is to find patterns of short-term swelling or deflation of a volcano, which help predict eruptions.

Background: If magma is added to or withdrawn from a shallow magma chamber, the ground surface above the chamber swells or deflates. Many volcanoes have magma chambers within or just below the pile of erupted material that forms their visible

structure. Magma flowing into such chambers from deeper sources just before an eruption will cause the volcano to swell, and magma moving through a "plumbing system" from one chamber to another will cause deflation of one part and inflation of another part of the volcano. For instance, in a Hawaiian-type shield volcano magma transfer from beneath the central caldera to a rift zone can be tracked by measuring the shape of the volcano, and such measurements help to predict when magma might begin erupting from fissures in the rift zone. But don't be fooled--volcanoes do not always swell measurably before eruptions; volcanoes drawing on deep magma reservoirs usually erupt without noticeable swelling.

Sometimes the swelling can give a very detailed picture of magma movement. An example is the swelling of the north side of Mt. St. Helens during March, April, and May of 1980, because a shallow intrusive done was forming beneath the surface. Sliding of the rock masses above that dome off the flank of the volcano triggered the destructive eruption of 18 may 1980.

Method: Volcanic deformation used to be measured by establishing baselines like the ones that surveyors use, then remeasuring them every few days. Prowling around on the flanks of active volcanoes with surveyor's transits made geologists' spouses and insurance agents unhappy, so tiltmeters were invented. A tiltmeter measures the tilt of the ground it is standing on, usually by bouncing a laser beam off a precisely-located distant reflector, and telemeters by radio a record of ground tilting to a central receiving station. These records are then analyzed by a computer, to provide a picture of how the volcano is deforming. Once a tiltmeter is installed (often by geologists in a helicopter, so they can leave in a hurry if necessary), it generally requires no further attention for many months. Of course, a large eruption can destroy many or most of the tiltmeters on a volcano, and if it seems that the volcano will continue to be active, they should then be replaced.

It may, under certain circumstances, be difficult to find volunteers to go back to replace damaged or missing tiltmeters. If you are unable to locate volunteers, you probably don't need tiltmeters to tell you that something dramatic is going on!

Analysis of Gases Emitted by a Volcano:

The purpose of this investigation is to use compositions of volcanic gases as guides to the chance that the volcano will erupt.

Background: Dormant and active volcanoes emit gases with compositions that can be very different from that of the atmosphere. These gases are usually mainly steam, from water percolating through the porous rocks typical of most volcanoes that is heated and escapes in fumaroles or steam vents. But if substantial quantities of magma are present close to the vents from which the gases are escaping, then the gases can be quite rich in other components.

Important magmatic gas components include carbon dioxide and especially sulfur dioxide. If the gases have reacted chemically at high temperatures, without much reaction at lower temperatures to

obscure the high-temperature imprint, hydrogen and carbon monoxide may be present in considerable amounts. Both the proportions of the various compounds in the volcanic gases, and their amounts may be useful in predicting volcanic activity. The proportions of the compounds are usually expressed as tons per day and calculated from the composition of a relatively small sample and an estimate of the total flow rate.

Method: In order to sample volcanic gases, you (or, more likely, some member of your team that you view as more expendable) must approach the volcanic vents quite closely and poke into the gas stream a long tube connected through a valve to a sampling reservoir. The reservoir was first pumped down to a respectable vacuum, and when the sampling geologist opens the valve, some of the gas stream is sucked into the reservoir. The valve is then closed, and the gas sample is rushed to a laboratory equipped to analyze it. (Speed is required so the gases do not have much chance to react with one another or with the walls of the reservoir, and change their compositions.) Gloves, protective suits, and gas masks are fashionable (or, if you want to stay on good terms with your insurance agent, required) wear for the sampling geologist, and it is prudent to pay some attention to what the volcano is doing, to minimize the risk that the geologist will be incorporated into the products of the vent. However, this investigation is really quite safe, in the opinions of most team leaders.

The results will be reported by the analytical laboratory as a general description of the gases found, with estimates of tons per day emitted by the volcano that was surveyed. Because of uncertainties in the whole process, these estimates are a bit up in the air. Proportions of magmatic gases are likely to be more useful to you as guides to the state of the volcano than are the estimates of the total amounts released by the volcano.

Ages of Rocks from a Volcano:

<u>Background</u>: Volcanoes often fall into an apparent pattern of activity, with some tendency to repeat whatever they have been accustomed to do in the past. Of course, it is easy to over-emphasize the regularity of these patterns, both because of wishful thinking and because of the human tendency to "see" regular patterns even when they do not exist. Still, it is useful to know about the past activity of a volcano when one is trying to guess what it will do. Even in a region that has been settled for a long time by humans accustomed to keeping written records, the time scales on which we can view historic volcanic activity are short compared to the time scales on which many volcanoes pass through their "life cycles". Earth scientists have invented many ways of determining ages of volcanic materials, such as lavas, to try to deal with difficulties posed by the comparatively brief human perspective. Techniques based on the decay of radioactive isotopes in rocks or minerals, or on other features such as luminescence of minerals, can be applied to rocks collected from volcanoes in your areas.

<u>Method</u>: You have some experts in determining ages of volcanic rocks on your team, or available to you because they are part of the staff of the

Age-Measurements Laboratory of Project Central, so you don't have to know a lot about the details of the methods they use. They will work on any volcano to which you direct their attentions, and will report to you the ages they have determined that lie between 1,000 and 9,000 years B.P. ("B.P." means "before the present"). In many respects, it is easier to determine ages of older rocks, but those ages are of little use to you in predicting volcanic activity within the immediate future, so the Age-Measurements Laboratory has concentrated (quite successfully!) on refining techniques for determining ages of young volcanic rocks.

In the past, when you have asked the experts on your team or at Project Central what the reported ages mean, they began arguing with one another, and it is many hours before you get any answers that make any sense, if ever. Consequently, when you see a plot of ages determined for a specific volcano, it is probably best to try to figure out for yourself what they might indicate. Look for the following kinds of features: Do the ages seem to clump in some way, or are they scattered in time without any recognizable pattern? Are there lots of young ages, close to 1,000 to 3,000 or so years B.P.? Or has most of the prehistoric activity of your volcano occurred longer ago? How many rocks were found to have ages in the interval between 9,000 and 1,000 years B.P.? Looking at the data in this way is not likely to give you conclusive answers about what that volcano will do, but it may help.

Volcanoes Instructor/User Manual

Introduction and General Information:

This manual contains suggestions about strategies for use of *Volcanoes*, suggestions for a pre-lesson, a pre-use test and a post-use test to assess student learning, discussions of useful literature, and background information for each of the major investigations. We have assumed that you have read the documentation. If you have not done so, please skim it now...

Some possible benefits of using *Volcanoes® Deluxe or Volcanoes®*

A. General Attitudes:

--Cooperation in dealing with severe natural hazards.
--Acceptance of ambiguity in observational data.
--Willingness to make decisions based on partial information.
--Prudent budgeting of resources (money, equipment, time).
--Understanding and acceptance of different interests which result in different occupational choices.

B. Skills:

--Reading improvement, though less in this version than in the old

--Use of Mouse (GS) and accurate typing on computer keyboard (Apple II and P.C.)
--Careful record-keeping/note taking
--Interpretations of scientific observations
--Use of maps
--Use of Cartesian coordinates
--Interpretations of histograms (bar graphs)
--Understanding of Earth's crust and origin of volcanic pipes

C. Knowledge:

--types of volcanoes
--volcanic terminology with regard to products of eruptions
--volcanic terminology with regard to chemical compositions
--geography where in the "real world" the various volcanic types may be found
--methods and results of remote sensing surveys

Infrared Scan--infrared emission; heat flow; effects of urban settlements on surface temperatures

Seismic Survey--types of seismic waves; effects of contrasts in wave velocities; generation of earthquakes; harmonic signals caused by motion of a fluid in a conduit

Electrical Conductivity--contrasts in electrical conductivity;

relationship among electrical and magnetic fields

--methods and results of other investigations

Tiltmeter Survey--use of lasers to measure distances and angles; deformation of volcanic edifices because of sub-surface movement of magma

Gas Analysis--chemical reactions among gases as a function of temperatures; chemical kinetics

Ages of Rocks--the concept that ages of geologic events can be numerically estimated; recognition of episodicity in volcanic activity

Maximizing gain from use of the program at home or in the classroom:

In many instances the information or activities required to acquire the above benefits and/or skills are only implicit in *Volcanoes®*, and you must highlight them for your students. Your judgement of how much your students are ready to learn should, of course, dictate how much enhancement of the educational value of the program you will do. (Bear in mind that statistics show teachers usually underestimate the amount of material students can learn.) In our experience with using *Volcanoes* in this way, students tend to be ready to learn more than we have expected.

Strategies for the Use of *Volcanoes®*

Note that, as in myths of may kinds *Volcanoes®* requires the participant to enter an imagined world, one in which the "rules of the game" make sense within their own context but differ from those of the real world. In the real world, children do not get to direct research teams, charged with the awesome responsibility of predicting volcanic eruptions, for instance.

Myths are universal in human cultures and always have as one of their primary functions that of imparting attitudes of central importance in the culture. We have planned *Volcanoes®* to impart attitudes that we are convinced are indeed of central importance in our culture, but many of these attitudes contradict signals your students receive strongly from other sources.

For instance, *Volcanoes®* can be played competitively, but is designed to reward cooperation. It is deliberately designed so that you may decide to use some combination of skill indices and budgets to decide who "wins". We suggest that you use the skill indices as that is the more important factor. You may wish to discuss this decision with your students, if they are mature enough.

There is a widespread perception in our culture that scientists use arcane tools to discover totally unambiguous knowledge. *Volcanoes®* attacks this mis-conception head-on, and teaches both that observations of complex natural systems inevitably generate ambiguity, and that one must nevertheless make important decisions based upon those observations and whatever interpretations can be made of them. We have tried to show a human side of science, in which fallible scientists use powerful tools but don't always understand the implications of the information they get thereby. That's a very close approximation of the real world, and it is worth pointing out to your students the contrast between reality and mis-conceived myth.

Some VITAL information for playing the game:

Children are commonly advised to budget prudently, yet they are also bombarded by inducements to buy things that they don't need. Volcanoes is designed so that anyone who plays recklessly, undertaking many investigations without thinking carefully about what they contribute to her or his understanding of probabilities of eruption, will do poorly. But it is also designed so that a player who hoards her or his budget will generally fail to predict well, owing to lack of information. You should encourage your students to plan their work, and remind them that their budgets will be replenished at the beginning of each turn. The provincial maps show locations of volcanoes relative to concentrations of population; ask your students to use that information to decide which volcanoes they will study first, and most intensively.

Not all kinds of volcanoes are equally hazardous, and not all investigations are equally well-suited for studying different kinds of volcanoes. Andesitic composite cones have a relatively great potential for destructive eruptions, although some cinder cones, because of their locations, bear

watching with care. Basaltic shield volcanoes erupt frequently but rarely do much damage or cause fatalities. Both andesitic cones and basaltic volcanoes develop shallow magma chambers, which can be detected by those investigations that are well adapted for that purpose. Cinder cones commonly erupt magma drawn from magma chambers at depths of ten kilometres or more. You may wish to discuss with your students the implications of that fact...

Classroom management:

In your class(es), the student-to-computer ratio is probably fairly large. If so, you can either divide the class into teams to play *Volcanoes®* with each member of a team assigned a specific responsibility, or divide the class into small groups that will work with the computer in turn. The first approach emphasizes cooperation and group discussion while the second may be too trying upon the patience of your students. We recommend the first approach, though it may take more planning and organization on your part.

Suggested roles for team use of *Volcanoes®*: keyboard operator, mapper for the Infrared Scan; recorder of seismic data, etc. All or some of these may rotate, if you desire. The teams may decide in advance which investigations to do, how to set warning levels, or to have a team captain who delegates authority on a rotating basis. We recommend that teams be no larger than four because if there are more, it would be harder for them to agree on what to do.

Evaluating the learning from use of the program:

Perhaps the best way to review what has been learned would be to assign a project (i.e. create model land-forms or some other non-verbal method of assessment) rather than tests. Students with marginal reading skills may encounter special difficulties both in playing the game and in taking the tests. We have data showing outstanding gains by slow readers when placed in a cooperative situation with brighter students. In any event, the above methods may help slower students and the only way to find out is to try them.

Pre-lesson Before Using Volcanoes® in the Classroom---Elementary to College Information

I. Volcanoes occur where magma (melted rock) reaches Earth's surface from its sources deep within the earth. The kinds of magma and the compositions of the rocks that form in volcanic activity, and the physical form of the volcanoes and their products, all help us to understand volcanism.

II. There are three major types of volcanoes. Their names tell us something about the kinds of rocks of which they are composed. (See glossary for definitions of compositions.)

For example:

a. Andesitic volcanoes are made of andesite. The word is pronounced: an-dis-it-ic and an-dis-ite, respectively. The last syllable of the second word has a long "i" sound. It is thought that the word may have orginated in the Andes where rocks of this type are in great abundance.

b. Basaltic shield volcanoes are made of basalt. This word has a short "a" sound in both words.

c. Cinder cones are made up of cinders which are usually basaltic in chemical composition. The chemical composition of the lava is the same as basalt. Only the form is different in cinder cones; cinders have been exploded into the air, and fall near the vent to form a steep-sided cone. Basaltic lavas that form shield volcanoes typically are very "runny" when erupted and build up volcanoes with

broad, gentle slopes. See glossary for further description of the forms lava takes when extruded.
III. Here are some mountain profiles labeled A, B, C.

IV. Here you might ask the students about whether they have lived close to active volcanoes or traveled to see them? If so, which types have they seen? (i.e Hawaiian = shield volcanoes, Pacific Northwest=andesitic, American Southwest=cinder cones.)

V. Which profile best describes Mt. St. Helens? Which profile best describes the Hawaiian volcanoes? Are the magmas the same? Can you give the reason why they may not be the same? (Answer: "A" for the first and "B" for the second. The magmas are not the same as one is andesitic while the other is basaltic. The location of the volcanoes is important and you might mention the "hot spot" under the Hawaiian islands. However, we expect mostly that students should be looking to differentiate between basically continental volcanoes which form chains and basaltic "rim" volcanoes such as those of Iceland.)

VI. People trained to study volcanoes are called volcanologists. Volcanologists study volcanoes to try to find out if they are apt to erupt in the near future.

VII. The Seismic Survey is an investigation frequently done on volcanoes. They are the result of Earth crustal movements. (Photocopy the section of the documentation booklet showing what the various

signals look like or draw them and have the students copy them.)

We envision that there are two levels of instruction with regard to understanding this concept. In the earlier grades students may just have to recognize which seism they are seeing but in advanced classes the underlying principles of this and the other investigations may be delt with in more detail. Very advanced students may wish not only to discuss how stresses build up in the Earth but might wish to build a model of what happens along a fault. A brief explanation of earthquake/volcanic occurances along lines of subduction zones might be given at this time. For any students the analogy between lightning/thunder (fast and slow waves, respectively, arising from a single natural event) and the arrivals of p-waves and s-waves from a distant earthquake to create a record of a teleseism is helpful.

VIII. The rest of the investigations, or an appropriate selection from them, should be introduced and explained. For the Apple II series of computers the word "code" may need to be explained. This word is used when a student is asked to choose an investigation or a volcano. The "code" is displayed immediately to the left of the choice on the screen. In the old version of Volcanoes®, you may change your mind by using the left pointing arrow to go over your choice before hitting "return". Once you hit "return" you have no chance to change your mind as the computer is acting upon your instructions. Also, you may re-enter the game if you are fired by simply typing in your name or a new name. You receive a new budget and a new skill index at that time and can continue to play the game with additional insight.

Use of the Pre-test

We expect you to present the class with a non-preparation test soon after introducing the pre-lesson. This test should help you to see where your students are and establish a baseline for working with your students. You may use the pre-test we have written, if it is suitable.

Volcanoes Around the World

The following list is only a partial list of volcanoes around the world because there are more than 500 of them. If we count those that are dormant or recently extinct, the number would be closer to several thousand. The volcanic belts are also the principal earthquake belts of the earth. They are primarily situated along the areas of weakness in the earth's crust which has fractures or faults. In general these areas of weaknesses seem to be around the rims of the ocean basins. This is the territory which borders such basins or the range of mountains which forms the boundaries of the continents. (...or in prehistoric times formed the boundaries of the continents.) Some of these are now enclosed inside the continents.

With a photocopy of a map of the world, draw a line around the rim of the Pacific Ocean beginning in South America, through the Andes Mountains up through Central America, Mexico and the western part of the United States to Canada and Alaska. From

there go west toward the Aleutian chain of islands to Asia and then south through Kamchatka, Japan, and the Philippines, the Moluccas, North Hebrides, New Zealand and South Victoria. Another great belt extends east and west. This begins in Central America, extends through the West Indies; then through the Atlantic by the Azores, Cape Verde and the Canary Islands. It runs through the Mediterranean, through Asia Minor and Arabia, and continues along the chain of the East Indies where it crosses the other line which you just drew encircling the Pacific and runs out into the Pacific at this point. You now have enclosed within your two lines a vast number of the most active volcanoes of the world. Within your somewhat circular chain, you have the Hawaiian Islands. There are many submarine volcanoes located in the Pacific Ocean. Many of the volcanoes that now form islands began life as submarine volcanoes far beneath the sea.

The American hemisphere has more active volcanoes than elsewhere. The two active volcanoes in the United States are Mt. St. Helens and Lassen Peak. Since the eruption of St. Helens, other "extinct" volcanoes have had their status revised to dormant. Kamchatka in the Soviet Union, Japan (Fujiyama), the Philippines, and New Zealand have active volcanoes. Hawaiian volcanoes continue to provide entertainment but at present only two are considered active.

In the Straits of Sunda, Krakatao stands as mute evidence of a tremendous eruption that affected the climate of the world. (Discussion of this occurance could form the basis for a paper.)

Iceland is the most important of the Atlantic centers. From twenty to twenty-five volcanoes have been in eruption there on an almost continuous basis, with a large number being from fissures.

Europe has its Vesuvius and Etna. There are many volcanoes in Africa also on the east and west sides of the continent. Volcanoes appear to exhist also along the border between Asia and Europe--the Thian Shan Range. Paricutin, in Mexico, is the most famous new volcano and is distinguished by having been observed since its beginnng in 1943. Also in Mexico, Popocatapetl (The name means "smoking mountain".) continues to belch sulfurous vapor from time to time, a reminder that the volcano may only be sleeping. Many parts of the world have volcanoes which are still classed as active. In New Zealand there are Mt. Ngauruhoe, Mt. Ruapehu, and Tangariiro which have not erupted recently.

This accounting is only a brief picture of the scope of the volcanoes which make up the rim of fire around our ocean basins. Should you desire that the students learn more about volcanoes, they could explore the eruptive history of some of the more famous volcanoes mentioned here.

Glossary of New Terms for Upgraded Volcanoes

Aa-- is a type of lava flow which appears as jagged or broken blocks.

Andesitic Volcano-- is a volcano built principally of andesite, an igneous rock with composition between basalt (poor in silica) and rhyolite (silica-rich). Andesites occur as lava flows and as pyroclastic materials (such as volcanic ash) erupted from volcanoes that are usually located near the edges of continents.

Ash-- is a fine-grained material formed as a result of volcanic explosions. This material may be erupted high into the air and then fall to form a bedded sediment on the ground, or it may be deposited from a seething turbulent ash flow that moves close to the ground. In the latter case, the ash deposit usually lacks prominent bedding (it is unstratified) and can retain enough heat so that the fragments weld together after it is deposited, to form an ignimbrite (welded ash-flow tuff).

Ash flow--refers to the movement of small solid rock particles along the Earth's surface rather than in cloud form in the air.

Asthenosphere--a portion of the upper mantle, generally 75 to 175 km below the earth's surface where the rocks flow freely owing to temperature and pressure.

Basalt--A fine-grained, sometimes glassy, basic (silica -poor, iron and magnesium-rich) igneous rock. Basalts are generally associated with oceanic volcanism, as opposed to the andesites which are associated with the margins of continents. Basalts are thought to have formed as partial melts deep within the bowels of the Earth.

Batholith--This is the largest of intrusive igneous bodies usually more than 40 square miles at the uppermost surface. This matter is molten when deposited but becomes solidified over time. Usually it is at the center of an intrusive body and may only be exposed by erosion.

Bombs--are large missiles of lava ejected explosively from a volcano while still in the molten state. These lava missiles acquire a rounded shape by being thrown through the air.

Caldera--This is a large crater, which may form in several ways, the most common of which is collapse during a large volcanic eruption.

Cinder Cone--This is a conical hill or small mountain, often with a truncated top in which is a bowl-shaped crater. It forms by deposition of cinders around a more-or-less circular vent during moderately explosive eruptions. Lava may erupt from the central crater or may break out at the base.

Core--the central or innermost portion of the earth.

Crater--a bowl or funnel shaped depression which

has been the outlet for the volcanic magma.

Crust--the outer rigid portions of the earth.

Epi-center--The point on the Earth's surface directly above the focus of an earthquake (the focus of an earthquake is the zone within the Earth in which rocks break and shift to cause the quake).

Eruption---A volcanic event which is the direct result of movement of magma (molten rock) beneath the Earth's crust.

Extrusive-----rocks ejected directly onto the surface of the Earth.

Fire Fountaining--Streams of lava shot skyward from a vent owing to the force of expanding gases that are being released from the magma as it approaches the surface. This structure is usually an elongated vent called a "fissure".

Igneous---rocks formed from the molten state, either intrusive or extrusive.

Ignimbrites---These rocks are formed by the welding or sticking together of still-plastic bits of glass and pumice in deposits of hot fragmental material. Flows which produce these deposits are called ash flows, and an alternative name for ignimbrite is **welded ash-flow tuff**. Ash-flow tuffs need not be welded, however, if they were deposited while cool. Deposits from mud flows, called lahars, sometimes have features like those of ignimbrites. All these kinds of fragmental flows can be very destructive.

Intrusive--These are rocks that form from the molten state but which solidify below the surface of the earth.

Island Arcs--These are volcanic islands, generally in arcurate rows, major features of which are chains of andesitic volcanoes.

Lahars--Fragmental deposits formed from mud-flows that sweep rapidly down volcanic slopes, usually more-or-less confined to stream valleys draining the volcanic edifice. Lahars often are directly associated with an eruption (e.g., the mud flow and lahar of the great eruption of Mt. St. Helens on 18 May 1980), but sometimes form when overly-steep volcanic slopes lubricated by rain or melting ice break loose in the absence of eruptive activity.

Lava--Molten rock (generally containing dissolved gases) which issues from Earth's interior onto the surface of the Earth.

Lithosphere---the crust and upper mantle which is located above the asthenosphere and is believed to include the plates.

Magma---all of the extruded materials which come out of a volcano. These include the gases, liquids, and solids.

Mantle---That portion of the earth between the crust and the core.

Mohorovicic discontinuity (Moho)--the boundary between the crust and the mantle.

Pahoehoe--a type of lava flow which has a ropy appearance.

Pyroclastic--Materials thrown out by a volcano in a fragmentary form, either a solid or a liquid, are called "fire broken" or pyroclastic.

Rift Zones-- These are elongated areas of fissures, formed where rocks are affected by stretching of the Earth's crust. These serve as channelways to bring magma to the surface.

Seismograph--An instrument designed to measure the movement of the ground during an earthquake. Modern seismographs telemeter their results to a central location where the data are analyzed to find out what kind of earthquake has been observed, and where it originated.

Seismogram--A record of the different kinds of waves that occur in an earthquake. Each type of wave moves through the Earth in a different way, and conveys different information about the materials through which it moves.

Shield Volcano--Through the repeated outpourings of fluid lava around a vent a cone can be constructed. In shield volcanoes, these cones have a low, broad profile with a small crater or caldera in the top. However, if the viscosity of the lava erupted increases, or if cinders are erupted, a small steeper-sided central cone develops, so that the volcano looks like a huge

Viking shield laid on the ground. (Shield volcanoes were given that name in Iceland.)

Sial--the upper and lighter granitic portions of the Earth's crust. The name refers to the composition of the material, mainly silica and alumina.

Sima--refers to the heavier basaltic portions of the earth's crust. The name refers to the composition of the material, mainly magnesium and silica.

Strato-volcano---an intermediate type of volcano built up of lavas and fragmentals (from more explosive eruptions).

Tuff---Ash deposits which are consolidated and in which the fragments are no larger than 2 cm. in diameter.

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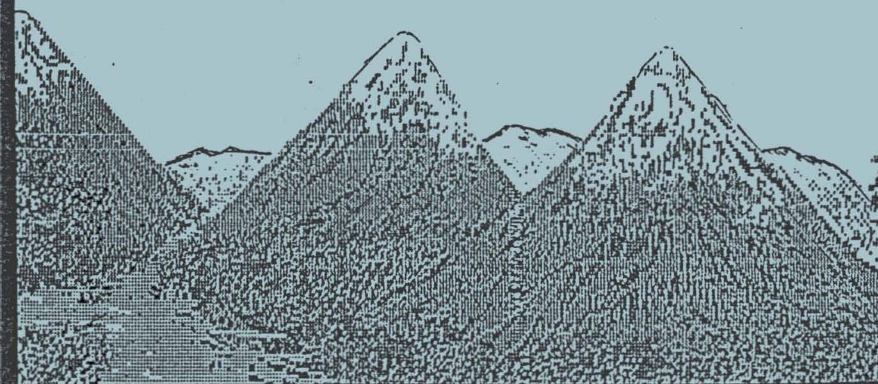

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