Defining and Sizing-up Mountains

By Steven Fry

What are the ten highest mountains in the world? Is Mount Everest larger than Mount McKinley? Does Mount Rainier rise higher above its base than Everest? Unbelievably, these questions have never been answered with any certainty, for the simple reason that mountains have remained essentially undefined.

There are some who may say defining mountains is impossible. However, the word "impossible" should be used with great caution, especially within the climbing community. Furthermore, classification systems are ubiquitous for such things as trees, animals, rocks and clouds—and although not perfect—these systems do help people better describe and eventually understand the world around us.

Various geographers and geologists have stated that a mountain must have: 1. 1,000 or 2,000 feet of local relief; 2. Relatively steep slopes; and 3. Prominence. But the terms "local relief" and "steep slopes" are always left undefined, which makes such definitions unworkable. Also, even in the rare cases where the prominence parameter is addressed, there is no agreement on whether a mountainous landform should rise 300, 400, 500 feet or more above ridge-level, before it is considered an individual mountain.

In 1981, following 12 years of academic, professional and recreational mountain study, I decided to make a serious attempt to establish a workable definition for mountains. I studied thousands of mountains and hills before I arrived at the conclusion presented in this article. My research mainly focused on Washington's Cascade Range, but I also studied other sections of the Cascade Range, the Rockies, Sierra Nevada, Appalachians, Himalayas, Andes, Alps, British Isles, Alaska Range and numerous other geographic localities.

Mountain Definitions

A mountain can be defined based upon the following three geographic parameters: A. Local Relief; B. Elevation; and C. Prominence. These three parameters are utilized in the mountain definitions presented in Table 1.

Local Relief / Elevation

The main function of the local relief criteria (Table 1, Rule 1) is to distinguish mountains from hills or plains. No attempt, however, will be made here to define plains or hills.

The 1,500-foot elevation requirement (Table 1,

Table 1: Mountain Definitions

As defined by Steve Fry

Descriptor	Rules: Any landform which:
Minor Mountain:	1. Has at least two sides, separated by 90 degrees or more, which drop from the summit area at least 1500 feet in 5 or less horizontal miles; 2. Is 1500 feet or more above sea level; and 3. Rises 250 feet or more above the lowest pass(es) between it and any higher landform(s), but less than 600 feet above at least one of these passes.
Submajor Mountain:	1&2. Satisfies rules 1 and 2 of a minor mountain; and 3. Rises 600 feet or more above the lowest pass(es) between it and any higher landform(s), but less than 1000 feet above at least one of these passes.
Major Mountain:	1&2. Satisfies rules 1 and 2 of a minor mountain; and 3. Rises at least 1000 feet in every direction above the surrounding terrain, including, if applicable, the lowest pass(es) separating the feature in question from any higher landform(s).

Notes:

(a) Major mountains with at least 5000 feet prominence in every direction, may be termed ultramajor mountains.

(b) Landforms with less than 1500 feet of local relief (see rule 1 of a minor mountain), may be termed hills, plateaus or flatlands, depending on their prominence. On the other hand, landforms which satisfy the local relief criteria for mountains, but fail to have 250 feet of prominence (see rule 3 of a minor mountain), should be given such names as: mountain points, spires, towers or ridges.

Rule 2) serves to exclude seamounts, and any geographical features which do not rise above sea level, from being deemed mountains.

Prominence

Prominence (Table 1, Rule 3) is used to separate mountains into three main groups: 1. Minor Mountains; 2. Submajor Mountains; and 3. Major Mountains; with major mountains having at least 1,000 feet prominence above ridge-level. (Mountains with at least 5,000 feet prominence in every direction may be termed ultramajor mountains.)

The minimum requirement for prominence is set low enough, i.e., 250 feet (see Table 1, Minor Mountain, Rule 3), so that most features which are popularly termed mountains are also geographically classified as such. Furthermore, because each range contains mountains of unequal prominence (for example: Lhotse Shar vs. Yalung Kang vs. Everest, in the Himalayas), the adjectives: "minor," "submajor" and "major" are applied to mountains to clearly delineate these differences.

Definition Applications

My mountain classification system enables people to effectively categorize mountains, whether the system is used by climbers or geographers to identify the highest mountains in an area (see Tables 2a-c), or by geomorphologists to describe the concentration of major mountains within a range. I have also utilized the mountain definitions to help decide the fate of geographic name proposals, upon the request of the Washington State Board on Geographic Names.

The definitions by themselves, however, do not achieve their full potential until they are used in conjunction with geographic mountain boundary rules.

Sizing-Up Mountains

To my knowledge, no one has ever before systematically measured the geographic size of individual mountains in the world. Therefore, I broke new ground when I devised a procedure that enables one to determine the precise geographic boundary, volume and rise above base for any of the world's major or submajor mountains.

Drawing Geographic Mountain Boundaries

The idea of drawing boundaries for individual mountains is really quite simple. One merely draws a line around the mountain in question so that all of the mountain's slopes and ridges are enclosed within the boundary.

Yet, in practice, the determination of where one mountain ends and another begins, or deciding

Table 2a: The Ten Highest Major and Ultramajor Mountains in the World

As determined by Steve Fry, from current topos, reports, and other sources

Major Mountains				Ultramajor Mountains			
Rank	Name	Height (ft/(m))	Location	Rank	Name	Height (ft/(m))	Location
1	Mount Everest	29,028 (8848)	China/Nepal	1	Mount Everest	29,028 (8848)	China/Nepal
2	K2	28,250 (8611)#	China/Pakistan	2	K2	28,250 (8611)#	China/Pakistan
3	Kangchenjunga	28,168 (8586)	Nepal/Sikkim	3	Kangchenjunga	28,168 (8586)	Nepal/Sikkim
4	Lhotse	27,940 (8516)	China/Nepal	4	Makalu	27,766 (8463)	China/Nepal
5	Makalu	27,766 (8463)	China/Nepal	5	Cho Oyu	27,906 (8201)	China/Nepal
6	Cho Oyu	27,906 (8201)	China/Nepal	6	Dhaulagiri	26,795 (8167)	Nepal
7	Dhaulagiri	26,795 (8167)	Nepal	7	Manaslu	26,780 (8163)	Nepal
8	Manaslu	26,780 (8163)	Nepal	8	Nanga Parbat	26,660 (8126)##	Pakistan
9	Nanga Parbat	26,660 (8126)##	Pakistan	9	Annapurna	26,545 (8091)	Nepal
10	Annapurna	26,545 (8091)	Nepal	10	Gasherbrum I	26,469 (8068)#	China/Pakistan

Notes:

(a) Other major mountains ≥ 8000 meters: 11. Gasherbrum I, 26,469 ft (8068m)#, China/Pakistan; 12. Broad Peak, 26,414 ft (8051m)#, China/Pakistan; 13. Shishapangma, 26,398 ft (8046m), China; and 14. Gasherbrum II, 26,362 ft (8035m)#, China/Pakistan.
(b) Other ultramajor mountain ≥ 8000 meters: 11. Shishapangma, 26,398 ft (8046m), China.
(c) # Heights for Karakoram Mountains are from: Chiacciaio Baltoro, 1:100,000, 1977, Dai tipi dell'Instituto Geografico Militare.
(d) ## Height is from: The Times Atlas of the World, (Comprehensive Edition), 1985, Editorial Direction by Bartholomew, John C., et. al..
(e) All other heights, including those of Mount Everest, Kangchenjunga, Lhotse and Cho Oyu, amongst others, are from: Carter, H. Adams, "Classification of the Himalayas", The American Alpine Journal, 1985, pp. 109-141; which is based upon Dr. Harka Gurung and Dr. Ram Krishna Shrestha's review of current 1;63,360 Survey of India topographic sheets, and 1:50,000 maps prepared for the Sino-Nepalese Boundary Agreement of 1979.

Table 2b: The Ten Highest Major and Ultramajor Mountains in North America

As determined by Steve Fry, from current topos and journal reports

Major Mountains				Ultramajor Mountains			
Rank	Name	Height (ft)	Location	Rank	Name	Height (ft)	Location
1	Mount McKinley (S Pk)	20,320	Alaska	1	Mount McKinley (S Pk)	20,320	Alaska
2	Mount Logan	19,524*	Canada	2	Mount Logan	19,524*	Canada
3	Mount McKinley (N Pk)	19,470	Alaska	3	Pico De Orizaba	18,405	Mexico
4	Pico De Orizaba	18,405	Mexico	4	Mount Saint Elias	18,008	Alaska/Canada
5	Mount Saint Elias	18,008	Alaska/Canada	5	Popocatepetl	17,930	Mexico
6	Popocatepetl	17,930	Mexico	6	Mount Foraker	17,395	Alaska
7	Mount Foraker	17,395	Alaska	7	Iztaccihautl	17,159	Mexico
8	Iztaccihautl	17,159	Mexico	8	Mount Lucania	17,147	Canada
9	Mount Lucania	17,147	Canada	9	Mount Bona	16,550#	Alaska
10	King Peak	16,971	Canada	10	Mount Blackburn	16,390	Alaska

Notes:

(a) * Height according to: Holdsworth, Gerald, "Another Round on Mt Logan", The Canadian Alpine Journal, 1976, pp. 68-69.
(b) # Height is a close estimate, ±50 feet.
(c) Heights for Canadian mountains are subject to revision upon publication of 1:50,000 topographic maps of the entire Saint Elias Mountains region, by the Canadian Department of Energy, Mines and Resources, in July, 1987.

Table 2c: The Ten Highest Major Mountains in California, Colorado, and Washington

As determined by Steve Fry, from current U.S.G.S. topos

California			Colorado			Washington		
Rank	Name	Height (ft)	Rank	Name	Height (ft)	Rank	Name	Height (ft)
1	Mount Whitney	14,491	1	Mount Elbert	14,433	1	Mount Rainier	14,410
2	Mount Williamson	14,375	2	Mount Massive	14,421	2	Mount Adams	12,276
3	White Mountain Peak	14,246	3	Mount Harvard	14,420	3	Mount Baker	10,778
4	North Palisade	14,242	4	Blanca Peak	14,345	4	Glacier Peak	10,541
5	Mount Shasta	14,162	5	La Plata Peak	14,336	5	Bonanza Peak	9,511
6	Mount Russell	14,088	6	Uncompahgre Peak	14,309	6	Mount Stuart	9,415
7	Split Mountain	14,058	7	Crestone Peak	14,294	7	Mount Fernow	9,249
8	Mount Langley	14,025	8	Mount Lincoln	14,286	8	Goode Mountain	9,220#
9	Mount Tyndall	14,018	9	Grays Peak	14,270	9	Mount Shuksan	9,127
10	Middle Palisade	14,012	10	Mount Antero	14,269	10	Buckner Mountain	9,114##

Notes:

(a) # Height is a close estimate, ±20 feet.
(b) ## Height is based upon field estimate, according to Fred Beckey.
(c) All heights can be converted to meters by multiplying the values by the factor 0.3048.

Fig. 2. GEOGRAPHICAL BOUNDARY OF MOUNT EVEREST

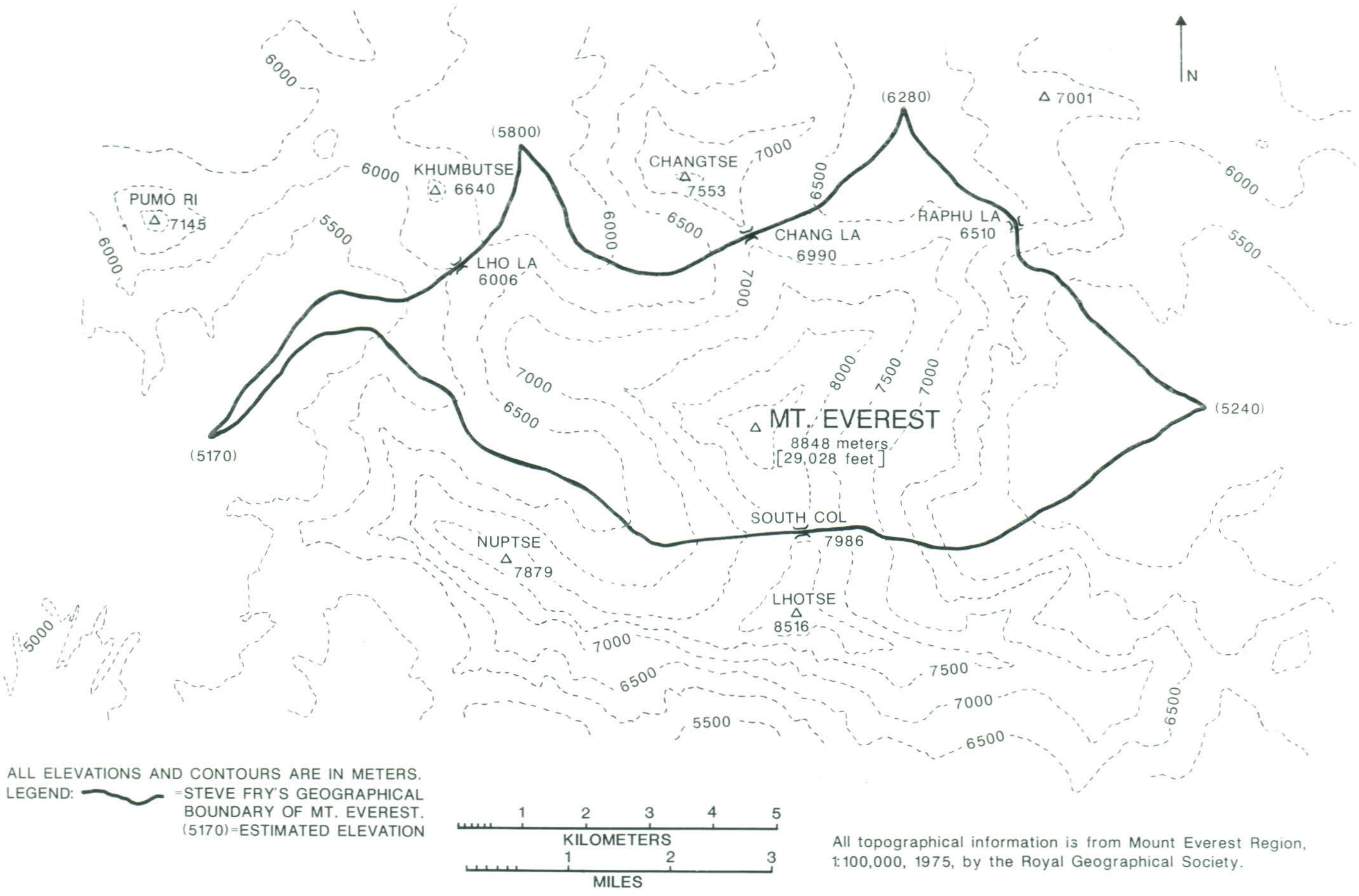

Fig. 3. **SAME SCALE GEOGRAPHICAL MOUNTAIN BOUNDARY COMPARISONS**

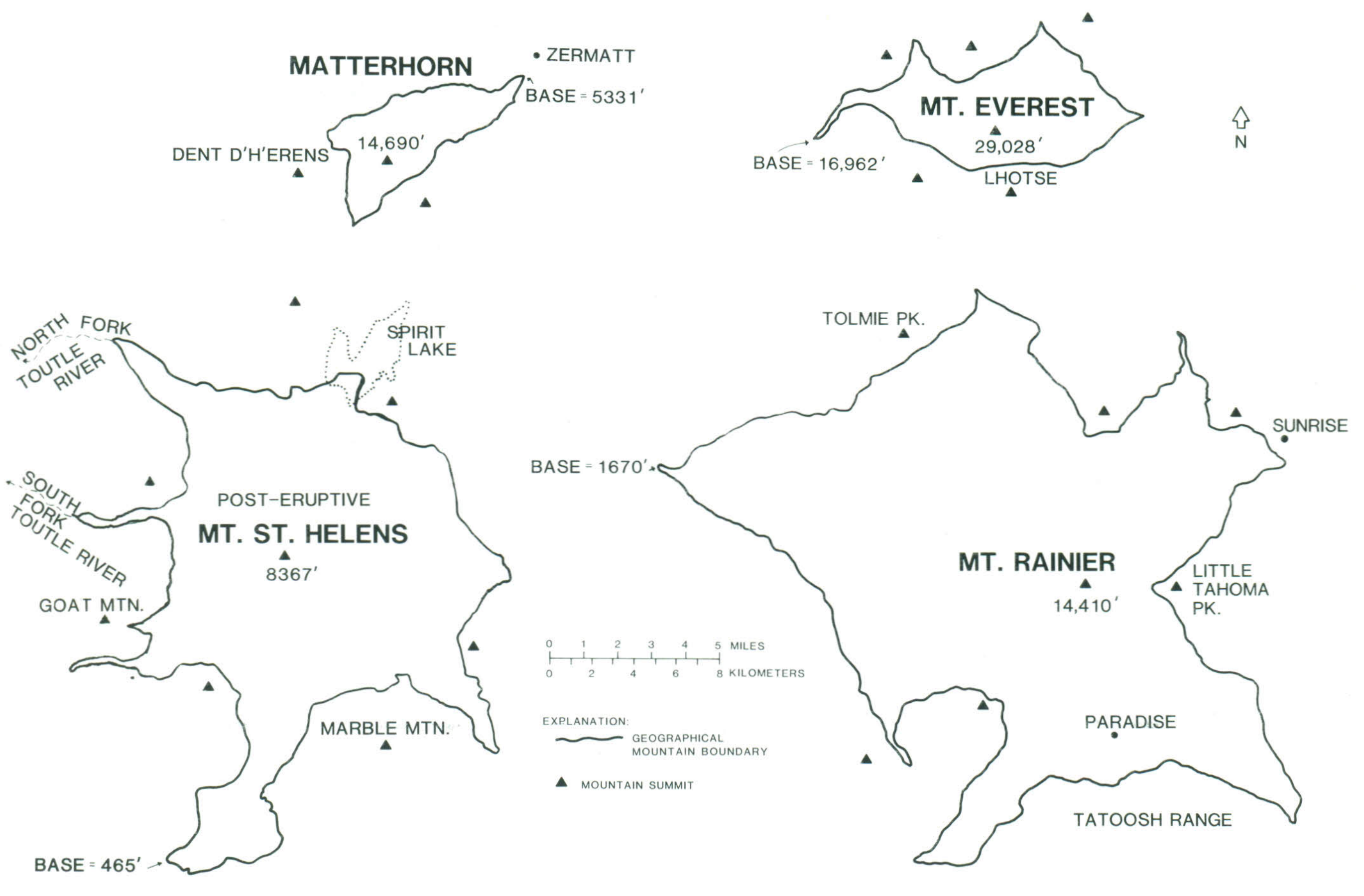

Figure 1: The North Cascades' Mount Redoubt serves as an excellent example of the prominence required for a major mountain. Redoubt is flanked on the left by the submajor "Twin Spires" and on the right by a few minor mountains. Photo by Steve Fry.

Table 3: Rules for Drawing Geographical Mountain Boundaries

As determined by Steve Fry

The geographical boundary:

1. Completely encircles the summit of the mountain* in question; and
2. Is the lowest line of points between the mountain in question and any surrounding submajor or major mountains; and
3. Does not enclose any large plateaus, flatlands or long low-sloping ridges**.

Notes:

(a) * Geographical boundaries are not drawn for minor mountains.
(b) ** Specifically, any ridge or slope descending directly away from the summit of the mountain in question, must drop at least 750 feet over any chosen horizontal span of 5 miles. (If the mountain does not have extending slopes or ridges which are 5 miles long, or greater, then it passes the test by default. In cases where the "5 mile rule" is not met, the geographic boundary is either drawn at: (i.) the lowest pass separating the mountain in question from the most prominent landform within the 5 mile span; or (ii.) an obvious inflection point.)

Table 4: Mountain Statistics Terminology

Height: The highest point in elevation of the mountain in question.

Base: The lowest point in elevation found on the geographic boundary of the mountain in question.

Rise Above Base: Height - Base = Rise Above Base

Area: The area within the geographical boundary of the mountain in question.

Volume: The total volume of land, glaciers, permanent snow, lakes and rivers above the base elevation of the mountain in question, and within the mountain's geographic boundary.

where the dividing line should be drawn between a mountain slope and a basin, is less obvious.

To resolve these quandaries, I looked back at nature. Mauna Loa's gentle slopes, the Shenandoah Mountains' long, level ridges, Rainier's multiple summits, Everest's knife-edge neighbors, Pikes Peak's surrounding uplands and a multitude of other mountains' configurations all had to be factored into the "equation." Based upon my research, I set up rules for drawing geographical boundaries that produce reasonable bounds for most of the world's mountains (see Table 3).

I use large scale topographic maps (1:24,000 - 1:63,360) to assess the topographic details of the boundary's route, and small scale topos (1:100,000 - 1:250,000) to actually record the boundary. It is also advisable to trace the mountain boundaries on vellum to avoid marring the topos.

For many of the world's rugged and/or small mountains, rule 2 (Table 3) is the only criterion needed to complete a geographic mountain boundary. In these cases, a mountain's bounds is determined by first identifying the lowest passes separat-

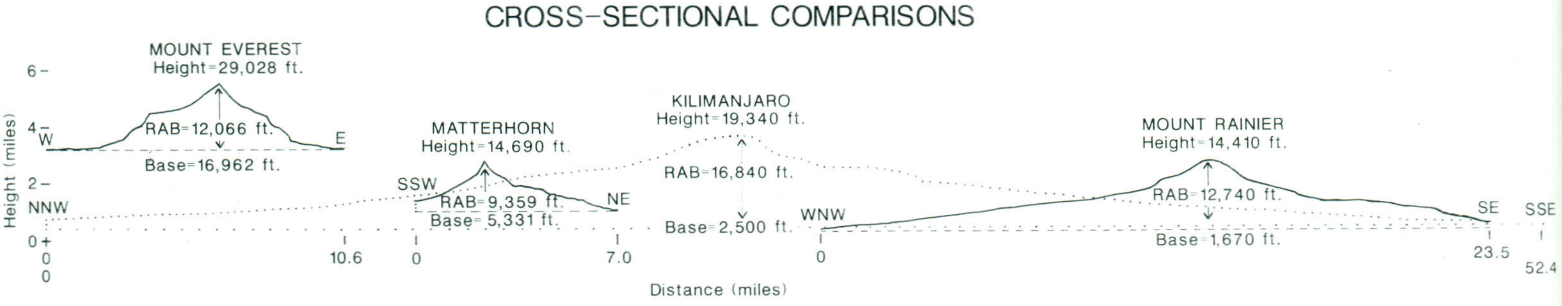

Figure 4. Cross-sectional views of selected mountains, illustrating the differences in size, steepness and elevation of these mountains. There is no vertical exaggeration. The widths of Everest, Matterhorn and Rainier are somewhat elongated due to bends in the cross-sections. The length of Kilimanjaro's cross-section equals 52.4 miles. RAB=Rise Above Base.

ing the mountain in question from all surrounding submajor or major mountains. Then, from these passes, lines are drawn downward, following stream or glacier concourses, until they all intersect to complete the geographical boundary. (See Figure 2, Mount Everest's Geographic Boundary).

An additional boundary drawing step is necessary if the mountain being outlined is large and/or gently sloped. In this case, after a mountain's boundary has been traced by adhering to rule 2 (Table 3), the enclosed area must then be checked to ensure that no extensive low-sloping surfaces are included. Typical problem areas are: 1. The interface between a mountain range and an expansive flat basin; and 2. Long, low-sloping ridges or glaciers, such as those found in the Appalachians and Rockies, or Alaska and St. Elias Ranges, respectively.

Note b, Table 3, specifies how to determine whether or not low-angled surfaces shall be excluded. These suspect surfaces must pass the "5 mile rule," which is measured along the paths of ridges or directly down slopes.

Mountain Statistics

Once geographical boundaries have been finalized, then mountain statistics such as rise above base (RAB), area and volume can be precisely measured and calculated for any mountain on earth.

The five main geographical mountain stats discussed in this article: 1. Height; 2. Base; 3. Rise Above Base; 4. Area; and 5. Volume; are defined in Table 4, "Mountain Statistics Terminology." All of these statistics are determined with the aid of topographic maps.

Height, base and rise above base are readily ascertained by simply applying the definitions given in Table 4. Conversely, measuring the area and volume of a mountain can be very time consuming. Depending upon the scale of the topo and the number of in-

Table 5a: Calculation of Mount Everest's Volume, via the End Area Method

Elevation meters/(feet)	Area miles^2	End Area Volume Calculation (miles^2 + miles^2)/2 x miles	Volume = miles^3
5170/(16,962)	19.91	(19.91 + 18.14)/2 x 0.1429 =	2.72
5400/(17,716)	18.14	(18.14 + 16.66)/2 x 0.1864 =	3.24
5700/(18,701)	16.66	(16.66 + 15.18)/2 x 0.1864 =	2.97
6000/(19,685)	15.18	(15.18 + 13.43)/2 x 0.1864 =	2.67
6300/(20,669)	13.43	(13.43 + 10.39)/2 x 0.1864 =	2.22
6600/(21,653)	10.39	(10.39 + 8.05)/2 x 0.1864 =	1.72
6900/(22,638)	8.05	(8.05 + 5.68)/2 x 0.1864 =	1.28
7200/(23,622)	5.68	(5.68 + 3.80)/2 x 0.1864 =	0.88
7500/(24,606)	3.80	(3.80 + 2.41)/2 x 0.1864 =	0.58
7800/(25,590)	2.41	(2.41 + 1.24)/2 x 0.1864 =	0.34
8100/(26,574)	1.24	(1.24 + 0.45)/2 x 0.1864 =	0.16
8400/(27,559)	0.45	(0.45 + 0.06)/2 x 0.1864 =	0.05
8700/(28,543)	0.06	(0.06 + 0.00)/2 x 0.1864 =	0.01
9000/(29,527)	0.00	---------------- x 0.1864 =	0.00
Total Area =	19.91 miles^2	Total Volume =	18.84 miles^3

Notes:

(a) End Area Volume Calculation Method:

$$\text{Volume} = \frac{(\text{Area 1} + \text{Area 2})}{2} \times \text{Elevation Interval}$$

Where: Elevation Interval = Elev. of Area 2 - Elev. of Area 1
e.g.: 6000 meters - 5700 meters = 300 meters, which = 0.1864 miles

(b) Areas were measured by Steve Fry, by using a K&E roller planimeter. Planimetering was confined within the bounds of Mount Everest's geographic boundary.

(c) Topographic map used to planimeter Everest: Mount Everest Region, 1:100,000, by the Royal Geographical Society, 1975.

(d) miles^2 = square miles; and miles^3 = cubic miles.

(e) miles^2 and miles^3 can be converted into kilometers^2 and kilometers^3 by multiplying the given values by the factors 2.590 and 4.168, respectively.

Table 5b: Mount Saint Helens' Pre- and Post-Eruptive Volumes

Elevation Intervals# (feet)	Volume Before Eruption* (miles^3)	Volume After Eruption (miles^3)	Change in Mount St Helens' Volume Due to Eruption (miles^3)
465-820	5.95	5.96	+ 0.01
820-1640	13.30	13.31	+ 0.01
1640-2461	12.04	12.08	+ 0.04
2461-3281	9.10	9.28	+ 0.18
3281-4101	5.37	5.54	+ 0.17
4101-4921	2.73	2.77	+ 0.04
4921-5741	1.44	1.42	- 0.02
5741-6562	0.87	0.76	- 0.11
6562-7382	0.51	0.35	- 0.16
7382-8202	0.26	0.10	- 0.16
8202-9022	0.10	0.00	- 0.10
9022-9842	0.02	0.00	- 0.02
9842-10663	0.00	0.00	0.00
	Total Before: 51.69	Total After: 51.57	Total Change: - 0.12

Net Volume Lost Above 4921 feet (1500 meters): - 0.57 miles^3

Net Volume Gained Below 4921 feet (1500 meters): + 0.45 miles^3

Notes:

(a) # Odd intervals are due to the conversion of contour elevations from meters to feet.

(b) * Eruption in question occurred on May 18, 1980.

(c) Volumes were calculated by Steve Fry, via the end-area method (see Table 5a), from planimetered area data.

(d) Topographic maps used to planimeter Saint Helens: Mount Saint Helens and Vicinity, Washington and Oregon, 1:100,000, by the U.S.G.S.; Dates topography mapped: Before Eruption = April, 1980, After Eruption = June, 1980.

(e) The exact same geographic boundary was used to measure both the pre- and post-eruptive volumes of Saint Helens. The common geographic boundary was drawn via the "After Eruption" U.S.G.S. topographic map, with the assistance of post-eruptive 1:24,000 U.S.G.S. topographic maps.

tervals selected, it may take two days to planimeter and calculate the volume of one large mountain! (Note: A planimeter is a precision instrument which can accurately measure irregular areas.)

The area of a mountain is ascertained by carefully tracing the boundary of the mountain in question, with a planimeter, and then converting the reading on the planimeter to either square miles or square kilometers.

To determine a mountain's volume, the areas inclosed by many separate contour lines are planimetered, from the base of the mountain, up to just below its summit. The volume is then calculated by employing the "End-Area Method" (see Table 5a). This method essentially calculates the volume of the mountain, from the areas planimetered, in a slice by slice fashion. Choosing closely spaced contour intervals results in more accurate volumes, but also requires ever increasing amounts of time to planimeter them.

Accuracy

The accuracy of the mountain statistics presented, in addition to requiring the acceptance of my exact mountain definitions and measurement methods, is dependent on three main factors: 1. Reliability of the topographic maps; 2. Measurement error; and 3. Calculational error. Where accurate detailed mapping is available, the total possible error for each mountain statistic is as follows: Height and Base (1%); Rise Above Base and Area (2%); and Volume (5-8%).

Findings

The results of my mountain measurements, for some of the more noteworthy mountains in the world, are listed in Tables 5a, 5b and 6, and graphically depicted in Figures 3 and 4. These tables and figures enable one to make unprecedented direct geographic comparisons between individual mountains.

Perhaps the clearest point the data illustrates is that volcanoes such as Mauna Loa, Kilimanjaro and Pico de Orizaba are many times larger than the high and supposedly big nonvolcanic peaks of the Himalayan, Alaskan and St. Elias Ranges. In fact, Mauna Loa's volume even when only measured above sea level, is nearly 95 times greater than that of Everest's.

Everest and K2 are also relatively diminutive when their RAB's are compared against Mauna Loa, Dhaulagiri, Machhapuchhare (20,150 feet), Kilimanjaro, St. Elias, McKinley, or even Rainier (see Table 6). However, Rainier is the only peak in the Lower 48

Table 6: Mountain Statistics for Selected Mountains of the World

As determined by Steve Fry

Name	Location	Volume ($miles^3$)	RAB* (feet)	Height (feet)
Volcanoes				
Mauna Loa	Hawaii	1775@	13,677@	13,677
Kilimanjaro	Tanzania	850	16,840	19,340
Pico De Orizaba#	Mexico	258	14,304	18,405
Mount Fuji	Japan	196	12,388	12,388
Mount Shasta	California	169	11,732	14,162
Mount Rainier	Washington	116	12,740	14,410
Mount Hood	Oregon	109	10,219	11,239
Cotopaxi	Ecuador	100	9,865	19,347
Mount St Helens**	Washington	51.6	7,902	8,367
Nonvolcanic Mountains				
Dhaulagiri#	Nepal	168	20,495	26,795
Mount Logan#	Canada	136	13,724	19,524
Mount St Elias#	Alaska/Canada	76	16,108	18,008
Pikes Peak	Colorado	75	7,779	14,109
Annapurna#	Nepal	75	14,245	26,545
Mount McKinley, S Pk	Alaska	65	14,290	20,320
Mount McKinley, N Pk	Alaska	60	16,100	19,470
Mount Washington	New Hampshire	30.1	5,453	6,288
Mount Everest	China/Nepal	18.8	12,066	29,028
Mount Cook	New Zealand	16.9	10,109	12,349
Lhotse	China/Nepal	15.8	12,930	27,940
K2	China/Pakistan	15.6	11,945	28,250
Mount Elbert	Colorado	14.0	5,333	14,433
Mount Robson	Canada	12.3	9,752	12,972
Matterhorn	Italy/Switzerland	7.3	9,359	14,690
Mount Whitney	California	7.0	6,141	14,491
Bonanza Peak	Washington	7.0	6,281	9,511
Grand Teton	Wyoming	2.3	7,085	13,770
Half Dome	California	1.5	4,882	8,842

Notes:

(a) * RAB = Rise Above Base
(b) @ Mauna Loa's volume and RAB data is for above sea level only, because the necessary bathymetric maps of Mauna Loa's entire massif were unavailable. Above its sea-floor base, Mauna Loa's RAB and volume probably exceeds 30,000 feet and 10,000 cubic miles, respectively.
(c) # Volume and RAB data for these specific mountains is subject to revision, because nondetailed topographic maps were used to measure them.
(d) ** St Helens data is post-eruptive
(e) Data measured by using current, government topo maps, except for Everest and Lhotse, whose volumes were measured by planimetering The Royal Geographic Society's, 1:100,000, 1975 Everest region map.
(f) If the East Buttress, South and North Peaks of McKinley are combined into one massif, then its volume = 181 $miles^3$, and RAB = 16,950 feet. However, if the geographical boundary of Dhaulagiri is modified to include mountains just as prominent as McKinley's N Pk, Dhaulagiri's volume would double and its RAB then equals 24,000 feet.

States to exceed Everest's RAB. And Rainier's RAB is achieved within an area which is more than 7-1/2 times greater than that occupied by Everest (Everest's and Rainier's areas = 19.9 and 152 square miles, respectively).

Certainly, what mountains such as Everest and K2 lack in bulk and RAB, they more than make up for in altitude and steepness. Everest's 16,692-foot base elevation alone, is higher than most every mountain in North America and Europe. Combine these peaks' extreme height with incredibly precipitous faces, and the results are truly astounding! (For an analytical comparison of the steepness of selected world mountains, see my article titled "Washington's Steepest Mountain Faces," *Signpost*, April, 1984).

Mount Saint Helen's

A popular notion regarding Mount Saint Helens' May 18th, 1980 violent, volcanic eruption is that Saint Helens' *entire* summit volume was pulverized and blown skyward over to Eastern Washington, Idaho, Montana and more distant localities. In actuality, nearly all of Saint Helens' summit mass slid

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down the volcano, in the form of a colossal landslide, and came to rest on its lower slopes.

My independent pre- and post-eruptive mountain volume measurements for Saint Helens, presented in Table 5b, prove that point. The reports within USGS Professional Paper #1250, titled: *The 1980 Eruptions of Mount St. Helens, Washington*, support my data.

According to my measurements, only 0.12 cubic miles of material was transported away from Saint Helens' geographic boundary. Of that total, approximately 0.06 cubic miles was blown skyward in the form of ash, (USGS Professional Paper #1250, p. 589). The remaining 0.06 cubic miles of mass flowed down the North and South Forks of the Toutle River, and other stream concourses, to areas outside Saint Helens' geographic bounds.

Overall Applications

In addition to the numerous geographical and geological comparisons that can be made between individual mountains and even entire mountain ranges, mountain statistics are useful in: 1. Evaluating how hazardous a volcano is to the surrounding populous. (Measurement of a volcano's volume is essential in determining how much material, in the form of a mudflow or catastrophic landslide, could potentially flow down valleys and through populated areas.); 2. Determining volumes of volcanic output and thus helping pinpoint potential geothermal energy sites; 3. Quantifying the erosional effects of glaciers, rain, temperature and/or wind, on the shapes and sizes of mountains; and 4. Discovering new geological and geographical trends or patterns, which will help unlock some of the secrets of mountain formation and structure.

Although the ideas and data presented in this article mark an important step in mountain research, much remains to be done. Large regions of the Himalayas, Karakoram and Andes still have not been mapped in detail, thus impeding in-depth geographical and geological study of those areas. Furthermore, there are numerous mountains throughout the world, for which good maps exist, that still await measurement. The sooner geographical boundaries are drawn and mountain statistics are compiled for all the mountains of the world, the closer we will be to a total understanding of the planet we live on.