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LETTER TO THE EDITOR

Comment on "Outburst Floods from Glacial Lake Missoula" by G. K. C. Clarke, W. H. Mathews, and R. T. Pack

Baker's (1973) paleohydrologic estimates of peak discharge from Lake Missoula flooding are 100 to 1000% larger than those calculated by the principal models in computer simulations by Clarke *et al.* (1984). I have compiled data from historic jökulhlaups which suggest the lower discharge values of Clarke *et al.* may be more accurate.

Clague and Mathews (1973) first noted a strong relationship between the size of glacially dammed lakes and the jökulhlaups they produce. For ice-dammed lakes the instantaneous discharge during floods can be approximated by determining the original lake volume and calculating

$$Q_t = K(V_t)^b \quad (1)$$

where K and b are constants which vary for each lake, and Q_t and V_t record discharge and lake volume through time. Clague and Mathews (1973) found that a strong empirical relationship exists between peak discharge (Q_{max}) and the initial lake volume (V), such that

$$Q_{max} = 0.0075V^{0.667} \quad (2)$$

TABLE 1. HISTORIC JÖKULHLAUPS

Location	Date	Lake volume (m^3)	Peak discharge ($m^3\ sec^{-1}$)	Reference
1. Strupvatnet, Norway	1969	2.60×10^6	150	Whalley, 1971
2. Mulakvisl, Iceland	1956	3.50×10^6	50	Rist, 1967
3. Ekalugad, Canada	1967	4.80×10^6	200	Church, 1972
4. Kaldakvisl River, Iceland	1965	6.20×10^6	260	Freysteinsson, 1972
5. Denmevatn, Norway	1937	1.16×10^7	1,000	Storm, 1938
6. Hazard Lake, Canada	1978	1.96×10^7	640	Clarke, 1982
7. Gjanupsvatn, Iceland	1951	2.00×10^7	370	Arnborg, 1955
8. Kverka, Iceland	1980	2.06×10^7	410	Rist, 1982
9. Katla, Iceland	1955	2.80×10^7	2,500	Thorarinsson, 1957
10. Vatnsdalur, Iceland	1898	1.20×10^8	3,000	Thorarinsson, 1939
11. Snow River, Alaska	1967	1.40×10^8	780	Chapman, 1981
12. Flood Lake, British Columbia	1979	1.50×10^8	1,200	Clarke and Waldron, 1984
13. Graenalon, Iceland	1973	1.60×10^8	2,000	Rist, 1973
14. Sululaup, Iceland	1978	1.75×10^8	3,000	Rist, 1982
15. Skeidararsandur, Iceland	—	2.00×10^8	2,000	Björnsson, 1977
16. Tulsequak Lake, Canada	1958	2.29×10^8	1,556	Marcus, 1960
17. Skaftardalur, Iceland	1970	2.37×10^8	1,500	Björnsson, 1977
18. Summit Lake, Canada	1965	2.51×10^8	3,260	Mathews, 1965
19. Strandline Lake, Alaska	1984	7.10×10^8	6,100	M. Sturm, 1984[b]
20. Lake George, Alaska	1958	1.73×10^9	10,100	Stone, 1963
21. Grimsvatnlaup, Iceland	1934	7.00×10^9	50,000	Thorarinsson, 1957

[a] Includes discharge from several channels and rivers.
[b] Personal communication.

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where volume is measured in cubic meters and discharge in cubic meters per second.

The jökulhlaup model of Clarke *et al.* demonstrates that other factors than initial volume affect flood discharge. Nonetheless, the 1973 empirical formula has predicted peak discharge during recent outburst floods in British Columbia with accuracy, if not sophistication, comparable to that achieved by computer models (Clarke, 1982; Clarke and Waldron, 1984).

Equation (2) is not suitable for extrapolation and estimation of Missoula discharges because it is based in part on Bretz's 1925 estimate of Missoula discharge through Wallula Gap. I have updated Equation (2) by removing Bretz's estimate and compiling new data from recent jökulhlaups in Alaska, Iceland, and British Columbia. For lakes which have drained repeatedly I have selected only the largest or best documented event. The new data set is more than twice as large as that compiled by Clague and Mathews (1973), and is summarized in Table 1.

I have fit a new regression line to the expanded data set (Fig. 1):

$$Q_{max} = 0.0065V^{0.69}. \qquad (3)$$

This expression is quite similar to (2), and when extrapolated for Lake Missoula estimates a peak discharge of 2.1×10^6 m^3 sec^{-1}, a value 77% of that of the most conservative model of Clarke *et al.* Equation (2) estimates only 1.2×10^6 m^3 sec^{-1}.

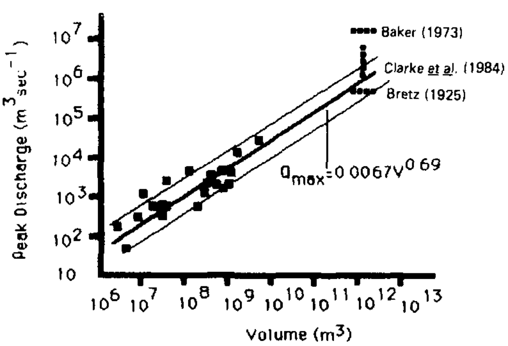

FIG. 1. Relationship between initial volume and jökulhlaup discharge of ice-dammed lakes. The correlation coefficient (r^2) is 0.86. Bordering lines define 85% confidence intervals.

Empirical data are necessary to evaluate computer models of natural processes. The empirical Equation (3) provides an independent check on other techniques used to study outburst floods, and is particularly appropriate for Pleistocene lakes where the original volume of lake water is probably the only parameter that can still be accurately determined. Equation (3) estimates a Missoula Flood peak discharge that compares favorably with the most conservative and realistic computer model runs of Clarke *et al.*

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