Journal of Scientific Exploration, Vol. *4,* No. 1, pp. 55–69, 1990
Pergamon Press plc. Printed in the USA.
0892-3310/90 $3.00+.00

Luminous Phenomena and Seismic Energy in the Central United States

JOHN S. DERR

U.S. Geological Survey, Albuquerque Seismological Laboratory, Albuquerque, New Mexico 87115

and

MICHAEL A. PERSINGER

Department of Psychology, Laurentian University, Sudbury, Ontario, Canada P3E 2C6
and
Centre in Mining and Mineral Exploration Research, Laurentian University

Abstract — Luminous phenomena (LP) that occur in seismically active regions appear to be temporally related to seismicity, even when the LP are not obviously earthquake lights (EQL). Within a time frame that required aggregates of monthly or annual increments of analyses, moderately strong ($0.50 < r < 0.75$) correlations existed over a 19 year period between the amount of seismic energy released and the numbers of reported LP within a central region of the United States. Other anomalous reports from the same data base were not significantly correlated with the energy release. Neither LP nor the other classes of anomalous events were significantly correlated with the release of seismic energy in the surrounding region that contained comparable area and seismicity. Thus, some types of reports of LP may be geophysical phenomena that reflect the temporal and spatial characteristics of tectonic strain.

Introduction

Sightings of luminous phenomena (LP) are often reported in the popular press with colorful descriptions (Saunders, 1978) which obscure their association with natural phenomena. We investigate the possibility that such an association may exist with earthquakes in the central United States, using a unique approach to the study of LP and their correlation with earthquakes. Our general hypothesis is that LP, now classified under the general rubric of UFO reports, should be significantly correlated with the release of seismic energy within the area from which the LP are observed. Other classes of UFO phenomena that do not meet the criterion of LP, should be minimally correlated with seismic energy release.

Luminous phenomena, at the time of an earthquake, are called earthquake lights (EQL) and appear to be a generally accepted phenomenon (Derr, 1973) even without an understanding of the mechanisms of production of the luminosity. Our recent work (e.g., Derr & Persinger, 1986) suggests the possibility of some relationship between earthquakes and LP which are spatially associated with earthquakes, but occur outside the time frame of a few hours to days at most, as would seem to be required for general acceptance of the EQL designation. The larger problem of finding a mechanism for production of geophysical luminosities from earth stress remains unsolved, although there is definite progress in laboratory studies (Brady & Rowell, 1986) and extrapolations to very large earthquakes have been made (Lockner, Johnston, & Byerlee, 1983).

We have found a similar systematic temporal relationship between the numbers of reports of LP and earthquake activity for other regions (Derr & Persinger, 1985; Persinger, 1983b; Persinger & Derr, 1984). This relationship is most obvious when relatively large (>10,000 km^2) areas and wide time frames (>1 month) of analyses are applied for periods of 10 years or more. Spatial increments that are much larger or much smaller than the optimal area do not reveal the relationship. Similarly, temporal increments that are much shorter or much longer than the optimal time frame do not display the pattern (Persinger, 1983c). We suspect that the determinants of these spatial and temporal parameters are related to the geological features of the region and the tectonic processes leading to earthquake activity.

The evidence suggests that many LP are very likely related to some form of solid-earth geophysical phenomenon. The LP are described frequently as reddish or whitish "lights," often displaying spherical shapes and showing erratic movements, usually with lifetimes of a few minutes. Reports extend back over 100 years and come from widely separated areas, (Corliss, 1982; Derr, 1973; Persinger, 1983d, 1984) suggesting the existence of a universal phenomenon.

In this paper, we test two hypotheses relating LP and earthquakes. First, a systematic relationship should exist in space and time between the release of seismic energy and some measure of the number of LP. We are assuming that the numbers of LP are systematically related to the number of LP reports. However, we are not assuming that there is a one-to-one relationship. Quite likely, since the reports are dependent upon a human observer, the actual number of LP may be greater than the number of LP reports.

Second, the maximum correlation between seismicity and LP should occur when considering earthquake energy measured from the same region in which the LP reports were taken. On the basis of concepts that were developed previously (Persinger, 1976; Persinger & Lafrenière, 1977), we hypothesized that earthquake measures within the area (of comparable size), surrounding the region, should not be correlated significantly with LP at all. If a peak correlation exists between LP and seismic energy within more or less the same region, then one could argue that the LP within the region are coupled with seismicity. However, if the strength of the correlation between LP and seismicity within any range of areas does not change appreciably (after their shared variance with seismicity within the LP region has been removed), then the role of a confounding factor, related to seismicity in general, could be argued.

Background

A significant problem has been to find reasonably comprehensive and objective measures of LP activity. This search requires us to examine the very heterogeneous UFO report data base. If we assume that the term "UFO" is overinclusive for a variety of different phenomena that only share an arbitrary label, then not all types of UFO reports should be strongly associated with earthquakes. If LP are strongly correlated with earthquakes and other types are not, then some bases might exist for the argument that these reports reflect actual environmental events. On the other hand, if all types of UFO reports are correlated with earthquakes, then some nonspecific human behavior reporting odd things might be associated with earthquake activity.

The six states (IL, AR, MO, IN, KY, TN) surrounding the New Madrid region in the central United States were selected as the study area (Figure 1). This region has had a long history of active seismic and LP activity. Earth-

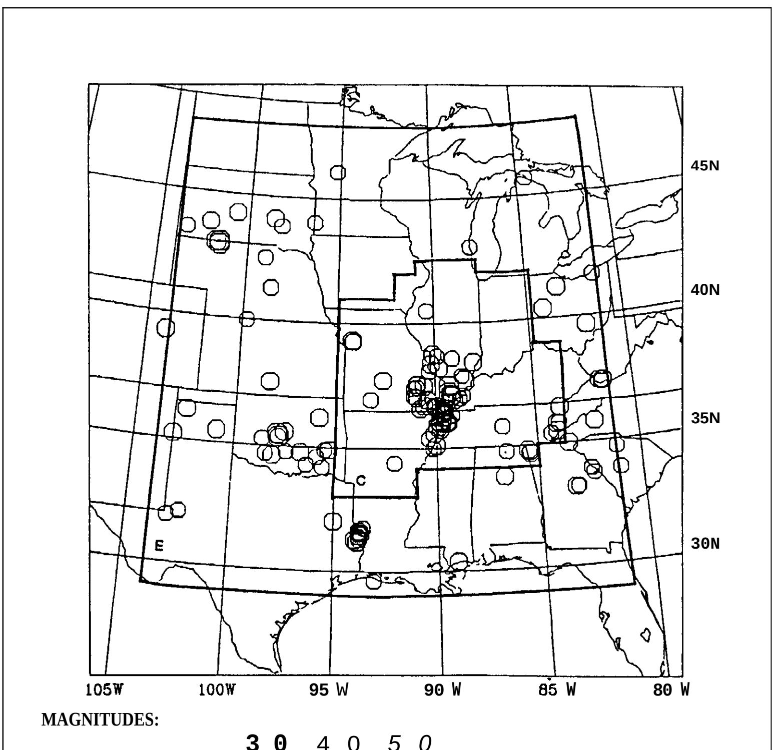

Fig. 1. Distribution of earthquakes (M> 3.0) within the central U.S.A. The six states from which the reports of luminous phenomena (LP) were collected are included within region *C*; the surrounding region, E–C, served as the control area.

quake data were obtained from the Nuttli data base (Barstow et al., 1981); it contains seismic events with magnitudes (m,) of 3.0 or greater. The LP and UFO report data were obtained from the UFOCAT file from the Center for UFO Studies (CUFOS) (Saunders, 1978). The period of analyses was between the years 1946 and 1966. This period was selected because most of the data for these years were derived from government reports and highlighted the most robust events. After about 1965, an abrupt increase occurred in the baseline of UFO reports. This also corresponded with a change in the procedure of data collection. Limiting the study to the period of relative uniformity minimizes the effects of its heterogeneity, although nothing can eliminate all of its problems.

Test of Hypotheses

To test the hypotheses, three classes of LP and two classes of other UFO reports were extracted from the CUFOS data base. Fortunately, these reports had been classified independently into 10 types. We have combined these into five groups reflecting our assessment of their relative characteristics, and separating out those most likely to be unexplained geophysical phenomena (Table 1). Two classes of specific LP (SLP): SLPa and SLPb, were designated. SLPa cases involved CUFOS report types three and four while SLPb cases involve report types five and six. Both classes were described as classic luminosities similar to reports from many other locales. SLPb reports con-

TABLE 1
Classification of luminous phenomena

CUFOS Data Base Type	Behavior of Objects	Classification in This Paper
0	Identified objects, Conventional explanations	—
1	Nocturnal lights—Stationary, starlike	Sky Lights
2	Nocturnal lights—Continuous trajectory	(SL, N = 326)
3	Noncontinuous trajectory, Single discontinuity	
4	Noncontinuous trajectory, >1 discontinuity	Specific Luminous Phenomena (SLP, N = 243)
5	Entered frame of reference of witness	
6	"Landed" in witness' frame of reference	
7	Occupants seen outside object	
8	Intelligent communication entailing language	Exotic Cases (EC, N = 34)
9	Lasting physical/functional effects on witness	
?	Unclassified	General Luminous Phenomena (GLP, includes SLP, N = 1134)

tained more unusual dynamic features (such as erratic movements) and more unusual behaviors (such as intrinsic color variations and surface gradients for luminous intensity) compared to **SLPa**. If both classes are variants of LP, then they should be correlated with similar strength to seismicity.

General LP (GLP) involved both SLP (both classes) and a category of reports left unclassified because of lack of details or followup. The formation of this general category was considered appropriate because factor analyses demonstrated that SLP were correlated most strongly ($r = 0.60$) with these unclassified cases but not the other two classes ($r < 0.30$) of UFO reports; they served as reference cases. These two classes were called sky lights (SL) and exotic cases (EC). Sky lights involved type one and type two reports that referred to unimpressive points of light that simply moved in a single trajectory. The EC cases referred to type seven, type eight and type nine cases—the strangest reports—and included the traditional "close encounter" phenomena. The SL and EC cases were also used as "controls" within the data base; we assumed that their variations over time would have been subject to the same variables of reporting as the LP; however, LP should be significantly correlated with seismicity while the SL and EC should not display this association.

Our analyses began by observing the gross temporal characteristics of both GLP (within region C) and the release of seismic energy from: (a) the region within which the GLP were reported (area C) and (b) the surrounding or "control" region (E–C) for the maximum duration of the CUFOS data base (1947 through 1977). Although we had decided to restrict our quantitative analyses to the years 1947 to 1965, for the reasons mentioned earlier, we wanted to visually examine the magnitude of the inflection in the rate of UFO reports after the year 1965. The earthquake energy was determined by the formula $10^{(1.5M+11.4)}$, where M is the magnitude of each seismic event.

Figure 2 shows the cumulative numbers of GLP within the six states (region C) and the cumulative amount of seismic energy released ($x10^{17}$ ergs) within region C and the surrounding region (E–C) that contained a comparable area. The rates of change in both GLP and seismic energy release from region C were relatively homogeneous for the years 1947 through 1965. However, a marked increase in the rate of GLP occurred in the year 1966; this change was associated with an extraordinary release of seismic energy about two years later within the same region from which the GLP originated. On the other hand, there was no obvious change in the rate of seismic energy release from the surrounding region. A second inflection point in the rate of GLP occurred in 1973; about three years later, another increase in the release of seismic energy occurred within this region but not from within the surrounding region.

By simple visual inspection, these results strongly support the hypothesis that there is a temporal relationship between LP and seismic energy release within a region. The correspondence between the inflection points of the LP and the release of seismic energy during the late 1960s also indicates that the

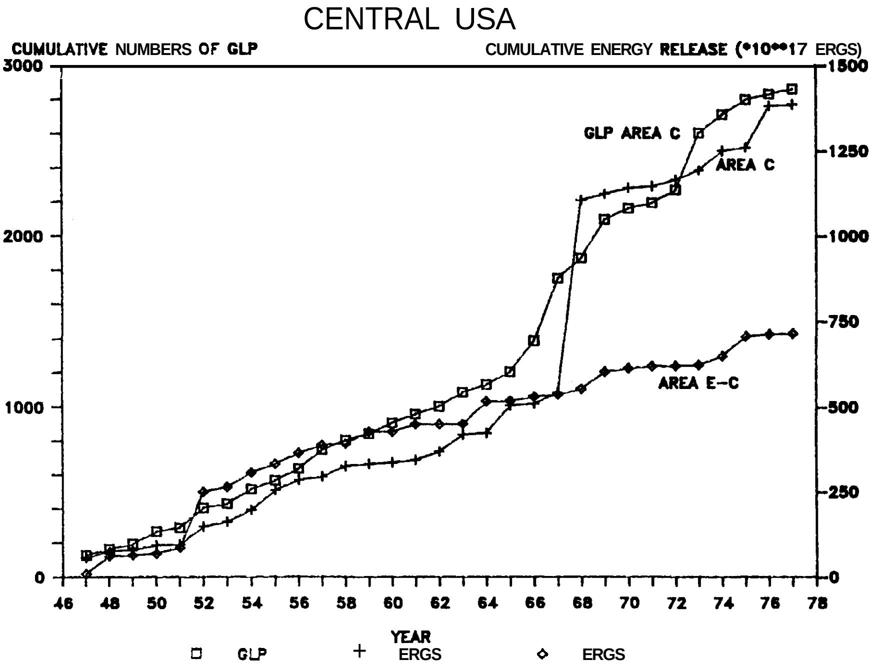

Fig. 2. Cumulative numbers of GLP (open squares) that were reported in region (area) C for the years 1947 through 1977. Cumulative seismic energy releases within region C (pluses) and the surrounding region, E–C (open diamonds) within the same period are also indicated.

CUFOS data base might actually reflect an increase in the rate of LP production rather than a change in report collection strategies as we had presumed. However, we decided to adhere to our original decision and confine our further analyses to the years 1947 through 1965.

Figure **3** displays a scattergram of the relationship between the total numbers of GLP per year and the total seismic energy release within area C per year during the analyses period. Both the Pearson-product moment correlation ($r = 0.51$) and the nonparametric Spearman rho (which is based upon rank ordering and minimizes the effects of extreme values) correlation (rho $= 0.60$) were statistically significant ($p < 0.01$). The correlations between GLP within region ***C*** and the seismic energy release in the surrounding (control) region were not statistically significant ($r = 0.10$; rho $= 0.02$). To determine if the relationship between LP and seismicity was coupled to energy release rather than the numbers of earthquakes, the numbers of seismic events per year within region C and the surrounding region were correlated with LP; none of these coefficients (all less than 0.20) were statistically significant ($p > 0.05$).

These gross results, based upon the numbers of GLP per year and the amount of seismic energy release per year, supported the hypothesis. The

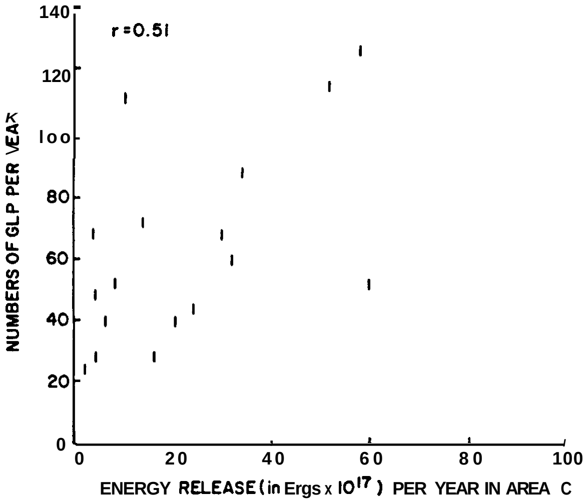

Fig. **3.** Total numbers of GLP (general luminous phenomena) per year within region ***C*** and the total seismic energy release per year within the same region.

absence of a significant correlation between the numbers of seismic events (regardless of magnitude) and GLP further indicated that they were associated with processes coupled to energy release rather than to the frequency of seismicity. Because: 1) the numbers of seismic events within region C (n = 127) and the surrounding region E–C (n = 121) were comparable and 2) the total energy release (Figure 2) within the two regions were similar, the LP-seismic energy relationship is not likely to be an artifact of discrepancies between the quantitative characteristics of seismicity within the two regions.

Yearly increments of analyses are arbitrary and do not necessarily reflect the optimal temporal coupling between a display of LP and its correlative release of seismic energy. Some of our analyses have suggested that the actual discrepancy in the occurrence of LP and seismic energy release may range between a few days to several months. Without some stimulus to synchronize the rates of strain accumulation, variable rates (and hence, variable periods between LP and seismic energy release) are expected. In accordance with the general concept of "tectonic strain," most LP occur during the protracted period of strain before the release of the seismic energy; a smaller portion of LP tend to occur after larger seismic energy releases, before the strain generated by the seismic events dissipates substantially.

To apply this concept to the present data, the numbers of GLP per month were determined. By visual inspection, months of GLP that were clustered together were separated into intervals. There were 39 successive intervals; their durations were variable and ranged between 3 and 11 months (the mean was 6.7 months). The numbers of total GLP, SLPa, SLPb, SL, and EC per interval, as well as the amount of seismic energy released in region C and the surrounding region, were then calculated.

As can be seen in Figure 4, there was a moderately strong positive correlation (*r* = 0.73; *p* < 0.001) between the total numbers of GLP per interval and the amount of seismic energy released per interval during this 19 year period. *A* weaker correlation (*r* = 0.30) also occurred between the numbers of GLP and the seismic energy released in the surrounding region. This association was attributable to the shared variance (*r* = 0.70) in seismic activity between the two regions. When a partial correlation was completed between GLP and energy release within the same region, with the variance associated with seismic energy from the surrounding region held constant, the GLP-energy association was still statistically significant (*r* = 0.53). However, when a partial correlation was completed between GLP and energy released within the ***surrounding*** region, with the variance associated with seismic energy from region C held constant, the GLP-energy correlation was –0.02. These analyses confirmed the dependence of GLP upon the energy released within the region from which they were reported rather than upon some general effect of seismicity.

Because the intervals selected to determine the relationship between LP and seismicity were variable, the possibility of a correlational artifact had to be eliminated. Partial correlation for the durations of the intervals did not appreciably change the strength of the relationship. Similarly, simply dividing the numbers of GLP by the numbers of months per interval and the total energy released per interval by the number of months per interval did not affect the strength of the relationship; the scattergram is shown in Figure 5.

We had also hypothesized that only SLP should be significantly correlated with the energy released within area C, whereas neither SL or EC reports should be associated with seismic variables. Such a result would be a type of

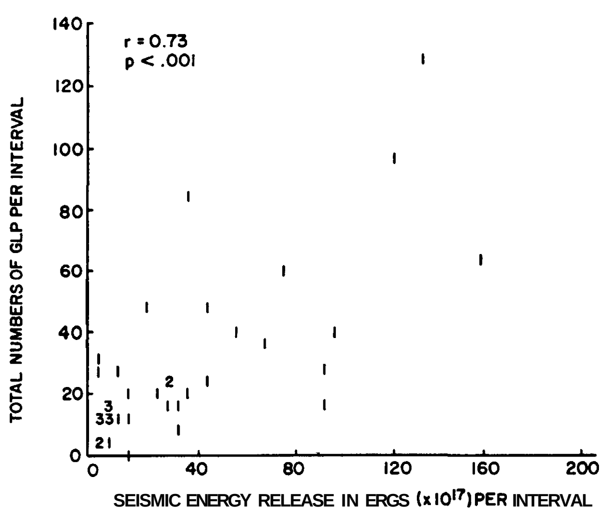

Fig. 4. Total numbers of GLP per optimal interval as a function of the total seismic energy (in ergs) release per optimal interval within region C. Numbers greater than 1 refer to the numbers of cases with the same values.

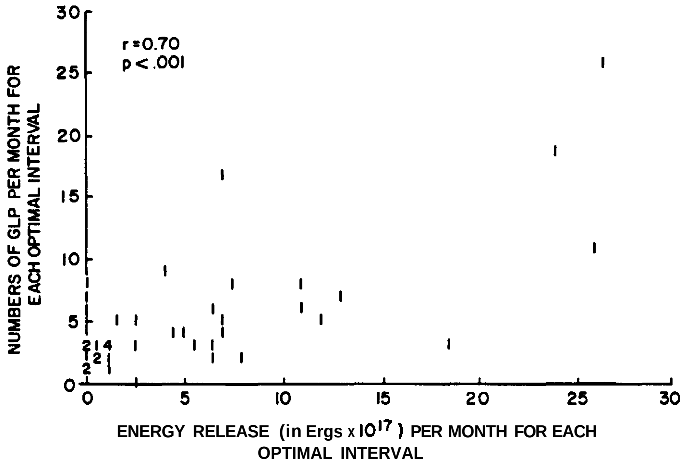

Fig. 5. Mean numbers of total GLP per month for each optimal interval as a function of the total seismic energy release (in ergs) per month for each optimal interval. Numbers greater than 1 refer to the numbers of cases with the same values.

discriminative validity, that would suggest that only a restricted portion of the UFO data base is likely to be physical phenomena that are coupled to seismic variables. As shown in Figure 6, the discriminative validity of our

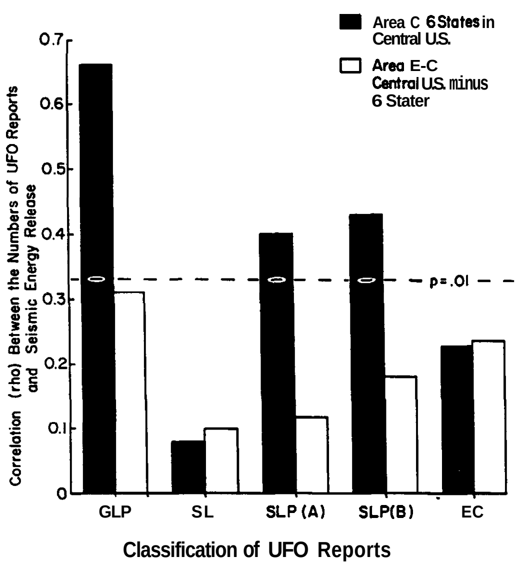

Fig. 6. Correlations (Spearman rho) between the amount of seismic energy release per optimal interval within region C (closed bars) and within the surrounding control area, region E–C (open bars) for different types of UFO reports that include: SL (sky lights), **SLPa,** and **SLPb** (two types of luminous phenomena that we assume have a geophysical basis), EC (exotic cases, that involve close encounters) and GLP (the general cluster of SLP and unclassified cases).

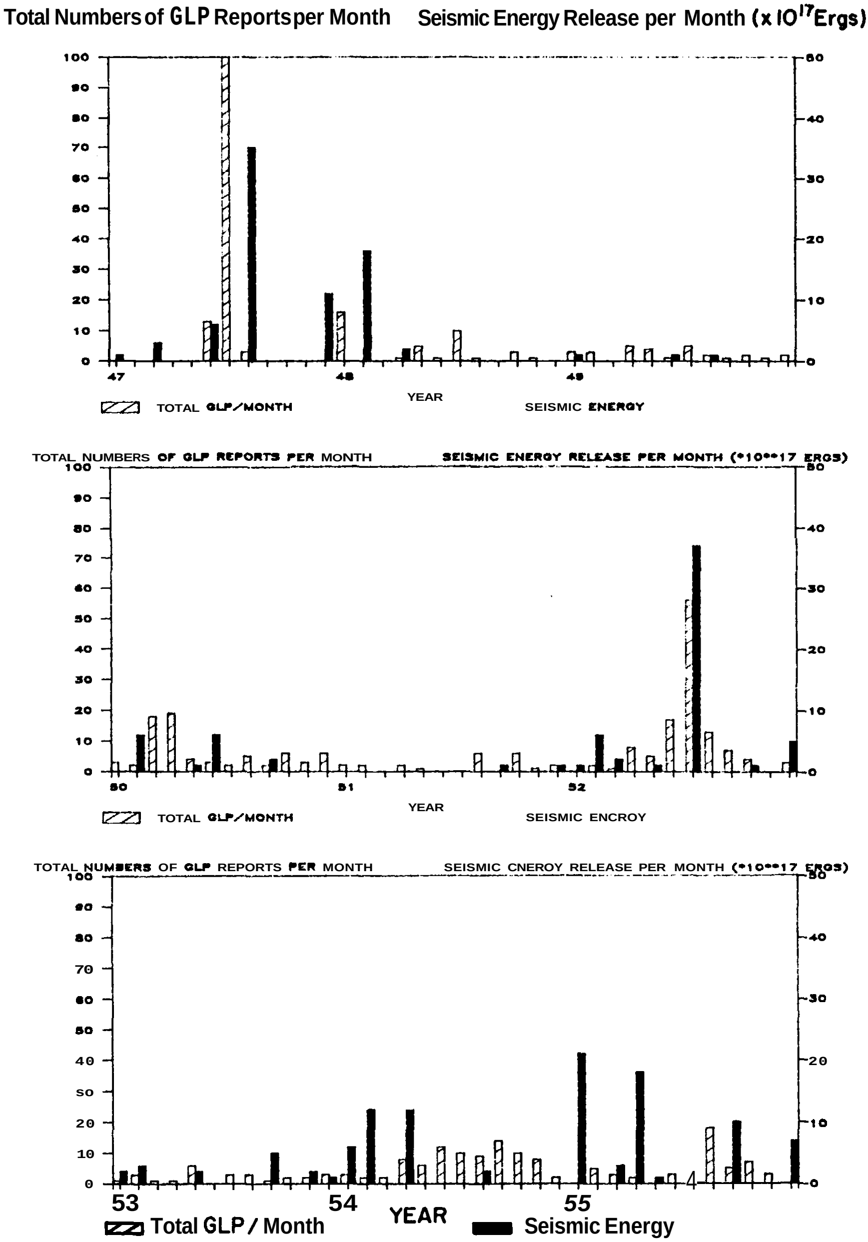

Fig. 7. a, b. The total amount of seismic energy (in ergs) released per month (closed bars) and the numbers of GLP per month (open bars) for the years 1947 through 1964.

assumptions is strongly supported. Only SLPa, SLPb and GLP (which is the sum of SLP and the unclassified cases) were significantly correlated (*rho* was calculated for all classes because of the mild skewness of distribution for EC

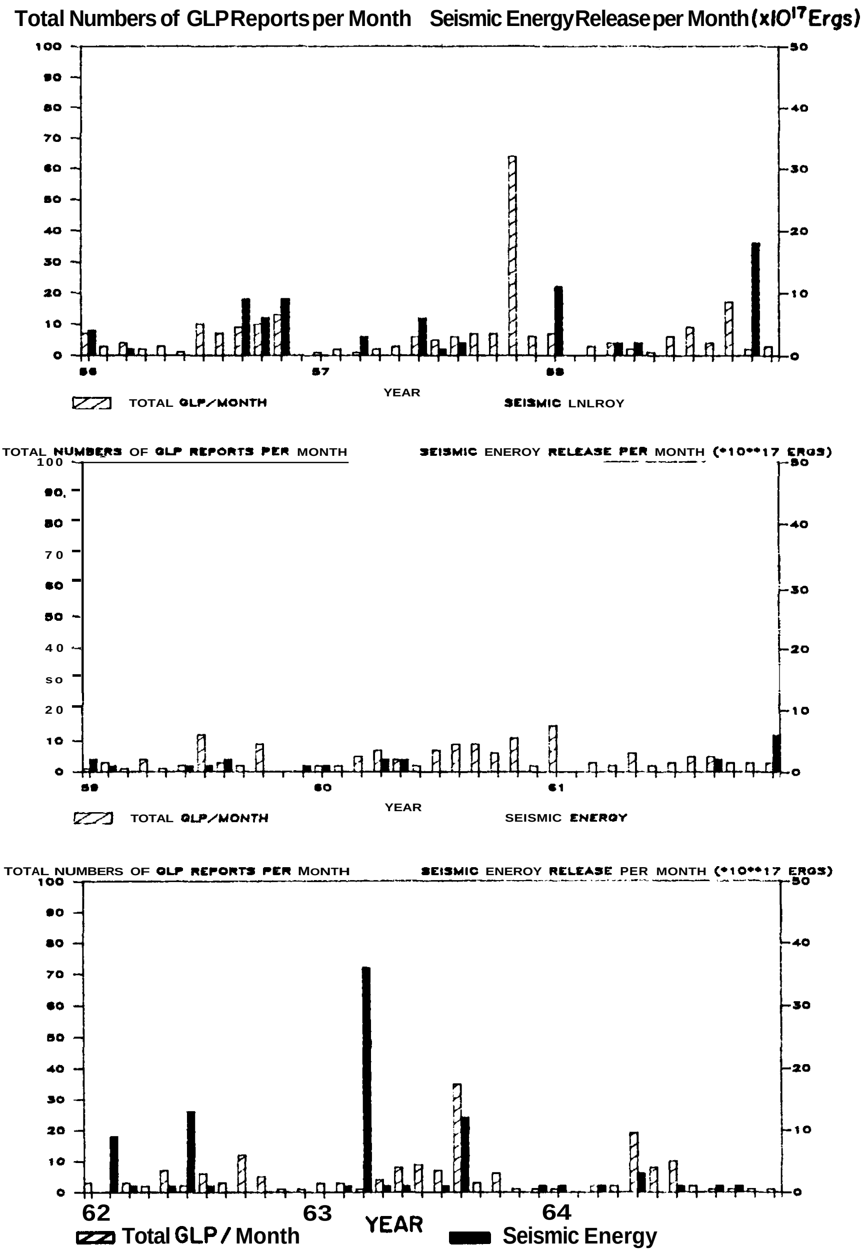

Fig. 7. *(continued)*

and SLPb) only with the energy release within the six states (black bars); on the other hand neither the numbers of SL nor the numbers of EC reports significantly correlated with the amount of seismic energy released from this region. None of the five types of reports were significantly correlated with seismic energy released from the surrounding region, E–C (open bars).

To emphasize the persistent relationship between the amount of energy released within the same region from which the LP were reported, monthly values for the total seismic energy released (black bars) and the total numbers of GLP (open bars) are shown in Figure 7 for the years 1947 through 1964. Luminous phenomena tended to occur during the same month or during the one to three months before the release of seismic energy. In fact, all of the 10 major periods of LP reporting (>15 GLP per month) occurred during the same month or within the three months before the most substantial releases of seismic energy. Conversely, 6 of the 10 most energetic seismic months were preceded by 1 of the 10 most active LP months. All but one of these most energetic seismic months (March, 1963) was preceded by a clear increase in the number of LP. Considering the nature and limitations of the data base, which relies almost exclusively on quasirandom observations, we suspect that LP did occur but were either not observed or not reported.

The large dispersion around the regression line for the relationship between the release of seismic energy and the number of GLP reports may have been affected also by contributions from quakes with magnitudes of less than 3.0. The Nuttli data base did not contain references to these events, yet "felt" events are quite common in the New Madrid region. Although most of these tremors would have had magnitudes of about 1.0, swarms or clusters may have been responsible for the periods of low-level but sustained reports of GLP such as during the latter part of the year 1961. In addition, these small quakes, which frequently are foreshocks and aftershocks of stronger (M > 3.0) earthquakes in the catalog, may have been associated with the increase in GLP during the one to three months before the larger earthquakes. Multiple clusters of weak seismic events (1.0 < M < 3.0) have been shown to be important components in the temporal correlation between LP and seismicity in the Yakima, Washington, region (Derr & Persinger, 1986).

Patterns of occurrence of LP and seismicity in other regions, especially where separated by hundreds of kilometers, suggest a possibility that LP might be related to migrating strain events. Although recent work in central and southern California has shown that regional strain tends to change linearly with time, the same study found marginally significant anomalies 12 to 18 months before two earthquakes (Savage et al., 1987). Derr and Persinger (1989) noted the clear convergence of LP towards the imminent seismic epicenter (M 4.4) in New Mexico; the migration began about 8 to 14 months before the quake and quickly accelerated towards the epicenter during the final 6 months. Whereas the average distance of most LP was normally greater than 300 km, LP increased in numbers and converged within 50 km of the epicenter during the period immediately preceding the quake.

Alternatively, observations of LP at great distances from associated seismicity might be explained if the crust or upper mantle contained heterogeneities which significantly enhance conduction of electrical energy over select paths. Our first order calculations from other data (Derr & Persinger, 1989) indicate that whatever process is involved with the distal distribution of LP may move between 100 to 500 km per year. It would be parsimonious if the effects of the hypothesized strain fields would be mediated through such select pathways; however this question cannot be answered within the limitations of the present analyses.

Conclusion

These analyses suggest that certain types of UFO reports, specifically those we have consistently defined as LP in this and other studies, (Derr & Persinger, 1986; Persinger & Derr, 1984, 1985) are closely associated in time and location with the release of seismic energy. One of the problems with this type of investigation is that the strength of the relationship between LP and seismic energy within this study might have been even greater if the number of LP reports were more indicative of the number of LP events and if the seismic data were complete to a lower magnitude threshold.

Many other problems exist with this type of retrospective study. Primarily, the correlations are statistical, rather than deterministic, and so leave open questions of actual cause and effect. We do not know the source of the energy, how it is conducted from the source to the observation point, how it is focused to create the luminosity, and how it continues for the duration of the sighting. To pursue these issues, a shift in methodology is required that would incorporate the variables that would reasonably be involved. Initial candidates would be the quantitative characteristics of the local geology and strain distributions. Some of these issues, such as the mechanism by which the energy is focused, should involve some fundamental process; its resolution may depend primarily on the technology and theory of modern physics.

There are several questions that are generated when the concept of mechanism is pursued. Does one impulse produce LP that can last significantly longer than ball lightening, or is some continuous or intermittent source required? Why do some seismic areas exhibit LP frequently, within the time frame of geophysical phenomena, whereas other areas do not? Is there, for example, something in the geology or hydrology of the region—or something related to some aspect of the geomagnetic field, that promotes the LP process?

In several of our studies, sudden perturbations in the geomagnetic field appear to have promoted the occurrence of LP. Interestingly, in the present study, the correlation between GLP per year and the product of the annual release of seismic energy from the central region and our typical measure of annual geomagnetic perturbation (the standard deviation of monthly averages of global geomagnetic activity about the annual mean) was 0.76. Although Mazzarella and Palumbo (1988) have hypothesized that variations in global geomagnetic activity might facilitate the stresses that precipitate earthquakes, how would geomagnetic activity influence the strain field? Do the geomagnetic perturbations affect paths of conductivity or evoke quantal releases of energy, manifested as LP, from the strain field? In general, our data do not support the proposition that sudden daily enhancements of geomagnetic activity are generally immediate triggers of LP because they often occur several days afterwards. The relationship is most evident with weekly, monthly and annual increments of analyses.

The LP data base is anecdotal, incomplete, nonuniform, and notoriously subjective. Positive results depend on judicious choice of the area to be analyzed: too small an area reduces significance, while too large an area adds noise to the analysis. Although we suspect that the optimal area of a region that shows the optimal coupling between LP and the release of seismic energy reflects the characteristics of the local crust, these parameters must still be established. For example in portions of North America where the crustal structure is reflected as focal accretions, the optimal distances required to discern the strongest relationship between LP and energy release are between 50 and 100 km. In portions of North American where the crust displays a larger more homogeneous architecture, the optimal distances may involve 500 to 1000 km.

Despite these limitations, we believe that the results reported here are valid and have theoretical significance for the understanding of LP. Similar and even stronger temporal associations between LP and the release of earthquake energy have been found in other regions, such as the Uinta Basin in Utah (Persinger & Derr, 1985) and Washington state (Persinger & Derr, 1984).

All of our analyses in which seismic energy has been calculated indicate that LP increase in frequency of occurrence when the amount of energy release per month exceeds about 1.0×10^{17} ergs. If this magnitude of energy is required, then experimental production of geophysical LP may be limited. One possible quasiexperimental approach that could lend deterministic support of the tectonic strain hypotheses involves areas in which there has been man-made seismicity. There are several areas, such as Denver and Rangely, Colorado, and western New York, where forced, subterranean pumping of large volumes of fluid have triggered seismic activity.

The unexpected, conspicuous relationship between the unprecedented increase in LP within the central United States during the late 1960s and the largest releases of seismic energy within that region for several decades implies the utility of this research. In other studies we have noted that the latency between a cluster of LP and the occurrence of a seismic event is positively related to its magnitude. If cumulative records of LP within other regions reflect similar profiles, then significant positive inflections in the yearly rate of LP reports might become an adjunct to earthquake forecasting.

Luminous phenomena have been reported for centuries. Frequently, their descriptions and their occurrence may have been masked or lost in the popular labels (Corliss, 1982; Persinger, 1983a). Wallace and Teng (1980), for example, note that the western world is predisposed to see UFOs, while the

same stimulus in China leads to reports of possible earthquake precursors. Our work suggests that the Chinese have found the more appropriate label.

References

Barstow, N. L., Brill, K. G., Nuttli, O. W., & Pomeroy, P. W. (1981). *An approach to seismic zonation for siting nuclear electric power generating facilities in the Eastern United States,* US Nuclear Regulatory Comm., NUREG/CR-1577.

Brady, B. T., & Rowell, G. A. (1986). Laboratory investigation of the electrodynamics of rock fracture. *Nature,* 321, 488–492.

Corliss, W. R. (1982). *Lightning, auroras, nocturnal lights and related luminous phenomena.* The Sourcebook Project, Glen Arm, MD.

Derr, J. S. (1973). Earthquake lights: A review of observations and present theories. *Bulletin of the Seismological Society of America, 63,* 2177–2187.

Derr, J. S., & Persinger, M. A. (1986). Luminous phenomena and earthquakes in southern Washington. *Experientia,* 42, 991–999.

Derr, J. S., & Persinger, M. A. (1989). *Denver area luminous phenomena, earthquakes and fluid injection at the Rocky Mountain Arsenal Well.* Paper presented at the Society for Scientific Exploration, June 15, Boulder, Colorado.

Lockner, D. A., Johnston, M. J. S., & Byerlee, J. D. (1983). A mechanism for the generation of earthquake lights. *Nature,* 302, 28–33.

Mazzarella, A., & Palumbo, A. (1988). Solar, geomagnetic and seismic activity. *Il Nuovo Cimento,* 11, 353–364.

Persinger, M. A. (1976). Transient geophysical bases for ostensible UFO-related phenomena and associated verbal behavior? *Perceptual and Motor Skills,* 43, 215–221.

Persinger, M. A. (1983a). Geophysical variables and human behavior: XV: Tectonic strain luminosities (UFO reports) as predictable but hidden events within pre-1947 central U.S.A. *Perceptual and Motor Skills,* 57, 1227–1234.

Persinger, M. A. (1983b). Geophysical variables and human behavior: VII. Specific prediction of UFO reports within the New Madrid states by solar-geomagnetic and seismic measures. *Perceptual and Motor Skills,* 56, 243–249.

Persinger, M. A. (1983c). The tectonic strain theory of luminosities (UFO reports): Determining optimal temporal, spatial and intensity parameters. *Pursuit, 16*(1), 21–35.

Persinger, M. A. (1983d). Predicting contemporary UFO reports in Great Britain from Charles Fort's data: An application of the tectonic strain theory. *Fortean Times,* 41, 58–65.

Persinger, M. A. (1984). Prediction of historical and contemporary luminosity (UFO) reports by seismic variables within western Europe. *Experientia,* 40, 676–681.

Persinger, M. A., & Derr, J. S. (1984). Geophysical variables and human behavior: XIX: Strong temporal relationships between inclusive seismic measures and UFO reports within Washington State. *Perceptual and Motor Skills, 59,* 551–566.

Persinger, M. A., & Derr, J. S. (1985). Geophysical variables and behavior: XXIII. Relation between UFO reports within the Uinta Basin and local seismicity. *Perceptual and Motor Skills,* 60, 143–152.

Persinger, M. A., & Lafrenière, G. F. (1977). *Space-time transients and unusual events.* Chicago: Nelson-Hall.

Saunders, D. R. (1978). *UFOCAT Codebook,* Evanston, IL: Center for UFO Studies.

Savage, J. C., Prescott, W. H., & Lisowski, M. (1987). Deformation along the San Andreas Fault 1982–1986 as indicated by frequent geodolite measurements. *Journal of Geophysical Research,* 92, 4785–4797.

Wallace, R. E., & Teng, Ta-Liang. (1980). Prediction of the Sungpan-Pingwu earthquakes, August 1976. *Bulletin of the Seismological Society of America,* 70, 1199–1223.