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Electrical Resistivity of the Geo-Materials in Monitoring the Earthquake Prediction

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Abstract: ***Electrical resistivity's of the geomaterials directly or indirectly depends on Temperature condition controlled by the geothermal energy. As one of rhe salient precursors of the earth quakeRsisistivities of the geo_materials decreases with the insuring earthquake at the 2nd stage: Rikitake (1976), Bolt1988, 1993 but on the recommendation of thermodynamic principle. In the Equation $\rho_t=\rho_0(1+\alpha_t)$ dependence of resistivity of geomaterials are never uniform for ranging from conductor to semicunductors:[1]at higher range of temperature. On the base of thermodynamics, caliberation of temperature affecting the resistivity of the material can be simulated with the equivalent amount of seismic energy >5 Mw magnitude. Time of ground motion can be predicted with the Gutenberg's Frequency –Magnitude relationship[2].With the Stacey's conservation equation[3] accumulated thermal energy can be transformed into mechanical energy (stress) sufficient for seismicity on the given area for given period on site of observation.***

Keywords: Resistivity, Seismicity, Geothermal energy, Earthquake magnitude and intensity

1. History

In the decade 30-40's statistical analysis on the basis of collections of past earthquakes since 1905 to 1940 were made case study for last 10 years experience of an area exposed to earthquake of city of Fruiti (Italy) & 2nd case of city of Park field California earthquake are suggestive of cyclic pattern. There is recurrence of 22 years[4] (Bolt 1988). The exception being of 1934 Earthquake in Assam, Bihar, (India) After 1966 Bolt (1988) predicted on this pattern to expect earthquake in 1988.

With the use of Geophysical precursors of Earthquake M=3 can be expected for a day Wary, & for M=4 magnitude in about 10 days,[5] Eliby (1980) For M=7,8 magnitude, occurrence is expected to be at 2 years and 6 to 7 years:[6] Rikitake (1976).

The above prediction bases for frequency Magnitude relationship by

$$\text{Log } N(M)=A-bM \qquad (i)$$

Where N(M) no of Shocks with Magnitude 7 A .... related to a and b by

$$A= a-\log(b)[\text{base log } 10] \qquad (!!)^7.$$

In the late 50's decade Gutenberg's equation. for heat flow and radioactivity of Geomaterials and Frequency-Magnitude relationship could open the steps in the context of predicting theory of earthquakes.

By VP/Vs ratio precursor used by Meyer (1977) Rikitake (1976) states: The ratio decreases by 10% in the 2nd stage of quake. Asada (1980) used radon emission (precursor) rising the level into the underground water during 2nd and 3rd stage.

Since 78 AD in china earthquake detector developed by Lau Jhang& in modern age with the use of five precursors; Meyer (1977) Bolt (1980) Asada (1988) Eliby (1981) et al. is the sufficient (considerably)means for prediction. On the basis of statistical **analysis[8] A**sada (1976), thermodynamic principle Anderson et al (1979) in context with the "evolution of thermal budget and Urey ratio: Urey (1955) & internal heating incorporates with Geochemical & Geophysical investigation,.[9] has been a step on the ladder of Gutenberg –Richter (1955a &1956b)'s frequency-magnitude relationship.eqn. Log E= α+βMin context with logN (M)=A-bM measuring seismic energy in dynes cm for prescribed magnitude & intensity arrival time proves fruitful to the mission of this paper.

In the perspective of structure & evolution of mantle and crust the most controversial subject in the solid earth science for the last few years eg. Ringwood (1975) Jeanoloj & Richter (1979) Davies (1981), Sphin & shburt (1982), Hedger et al. (1985) have opened the way for modification in the plate tectonic theory &seafloor spreading concept; N, L. Coundie (1979) W. Hess (1960) respectively. Internal heating surface heat flux (convective); Christiansen (1982) Sopher & Schubert (1982) was put up for energy balance in plate tectonics being improved by Solomotov (1975).

In the thermal evolution of earth's mantle, crust; Anderson (1985) Ita and Strixrude (1979) ONion's et al. (1979) Waserberg (1979), RD Van der. Hilst (1997) have presented seismological structure of lower mantle at 660 Km. as source of seismicity.

Though the list of works in the sphere of seismicity & related predictive eqn.one worth illustration are Aries intensity (1970) equation[10] adding to the differential solution in the Aires intensity equation. (1970) is another step in this field. However, recently accepted theory for the prediction of earth –quake ground motion ;[11]Dowrick &

Rhodes (1998) Doser et al. (1999) Zhao et al. (1997) Estourn et al. (2005, a, b) and recently by P.J. Stafford, John. B. Berril, J.R. Pettinga (2008) in J. Seismol(2009) are notable

Principles involved in the calibration of temperature by triggering Geothermal Energy in form of interior heating and heat-flux (convective) Urey (1955 a, b) accumulated as seismic energy are laid in following steps.

1) During transformation of energy (Geothermal into Mechanical and Seismic) temperature remains constant;[12].2. Phase transformation of energy additional energy in supplied or conserved in accomplishing useful mechanical work, keeping P or T const.,3. Immediate result of law of thermodynamic principle is Gibb's free Energy concept.[14]. dG=dE -= Tds+Pdv (ii) [15]Reference- Brian Mason Geochemistry.
2) Where dE=change in energy of a given system. T= absolute temp. of the system at which discussion is to be sought.ds=dq/dT or dq = Tds, Further, Pdv= pressure, × change in volume. Earthquake, as the stress drops in form of accumulated seismic energy (is due to Geothermal stress?) Within the Mantle (Upper) and crust boundary:[16] For the magnitude M>7 released seismic energy, by Gutenberg equation
3) Log E = (α+β)M................................... … (b)

   or n(E) = ...1⁄lnβLog(E- α) =Log(E-α) (8)

   β of frequency Magnitude relationship is simplified further

$$'(E)= C(E)E^{-k} \qquad (10)^{17}$$

For placing the desired Me Energy Ee expected can be obtained by eqn.

$$Me. =Mt=logEt-\alpha \qquad (12)$$

β by the equation 9-12) L.Guanieri et al.(1980-81)

a b and α, β are constant factor. Which depends on the value of a and b and can be obtained by statistical moments UTSU (2) By fixing derived value of seismic energy for desired M>5 magnitude we observe with the change in temp. For equation 9 to 12

H=mcT, C=specific heat of the materials under observation.\

We have,

$$[.e^{tdt}+dt.e^{\Delta T}]+\text{for } M=5$$

magnitude after putting

$$dE=j.e^{H+t}dt \qquad (13)$$

dE = Seismic Energy, H= thermal energy
dt = time, J= joule's const. Since temperature exponentially rise forE , H , dt , J= being const.For no moment a short interval of time thermal energy increases exponentially and value sufficient to bring magnitude (M>5). Again= mcT in........... Eqn (13) We have, dE proportional to $e^{\Delta H}$ and $e^{\Delta t}$ and after joint variation
dE is proportional to $e^{\Delta H+\Delta t}$.dt-------------------(13)Where dE=change in seismic energy achieved by transformation of thermal energy (accumulated) –ref J and dt are proportionality constant, J=Joul's const.dt= derivative for time.[18]

$$\int dE = J. \int e^{\Delta m cT + \Delta t}.. dt$$

Log E= logJ+ $\int \log e^{\Delta H+\Delta t}dt$ _ after taking log ie Log E = Log j +$^{emc\Delta T+\Delta}$t _mc[logE-log J)

Or, LogE-log J+mc (logE-logJ)=$e^{mc\Delta T+\Delta t}$

$$(LogE-LogJ)= \frac{e^{mc\Delta T+\Delta t}}{1+m}$$

$$\text{I.e. } \log E = \frac{e^{mc\Delta T+\Delta t}}{1+mc} + \log J \quad .... (1)$$

Where, J=joule's constant.
m= mass of entire rock system under observation, C= specific heat of rock (Geomaterials)
T=average rise in temperature of the geomaterials calculated by

ΔH=mcΔT from the energy conservation equation of Dacey(1981)[19] .Where J= joule's const. m= mass of the geomaterials (rocks) under observation ΔT= rise in temperature up to which the resistivity of rocks changes (decrease or increase depending on the nature of materials used).Δt=time span from thermal heating (internal)and heat flux (convective)Dziewski and **Anderson (1981), WASSESBERG (1979),Onions(1979) Van der Hilst et al(1997). To reach Δt** temperature, c=specific heat of the geomaterials.

What so ever the thermal budget of earth's mantle interior heating and cooling may produce heat energy and heat-flux, ie, H_m&H_{oc}=(Heat production in oceanic region) **and Q_m &Qcc(=het –flux produced at mantle- crust boundary. and (Cc continental region)[20]**Total balanced global heat production is controlled by the equation. BE =(U) = (($Hm+H_{oc}$)/($Q_{om}+Q_{cc}$)_______________(A)
and Convective Ur=Hm/(Qom+Q_{cc})............................(B)**

Source: Korenaga;Urey Ratio earth's mantle Heating (2007)p no-3.

On the basis of geochemical & geophysical investigation at 660 Km the lower mantle canbe displayed as the unified model for the seismic discontinuity[22]. (R. D. Van. der. Hilst.1997).this supports the focus at deep sheeted generation. In the perspective of BE convective heat flux and surface heat –flux from all source (Urey1955, 1956) the rate of heating is assimilated with rise of electrical flux by the equation.[$]

$P_t=\rho_0(1+\alpha T)$ and T= increase in temperature ρt= resistivity at T temperature and ρ_0= resistivity at initial temperature; [21]Rein et al.(2004). Which shows the change in resistivity's during the 2nd and 3rd stage of earthquake mentioned by Rikitake (1976) in the paper of Chris gray(2007).

Mission of the paper is expertise in the equation18)and (19) in his paper .ie

$$\theta_{ff}=\theta_0+(\theta_i-\theta_0)e^{-kt} \qquad (!8)$$

$$\rho_t=\rho_o e^{-kg/}kBt \qquad (19)$$

Which is supplemented in the derivation of dt, ΔT& Δt in the equation (14)Further equation (14) has m= mass of the bulk of rocks under observation c= specific heat of the rock materials, Δθ= average rise in temperature for the rocks under observation.

II nextly standard value for the global surface heat-flux~44TW(Pollack et al.(1993)combination of heat flux for oceanic and continents respectively ~32&12 TW were contributed to sum as average of ~46 TW in modified value [23].(Jaupat et al. (2007)

Prior to plate tectonics advent calculation of thermal history of globe was based on thermal conduction Lord Kelvin(1863),Jeffrey(1924),Macerated(1959)but the concept of mantle convection accepted in (1970)as so called parameterized convection" in which thermal evolution is based on convective heat loss [24]. Energy conservation eqn. Dacey (1981) for the entire planet can be simulated to equation 14 with the equation (8) in this paper. As

$$\frac{C\, dT(ti)}{dt.} = H(t)- Q(t) \quad (15)$$

Where c= specific heat of the globe~$7.10^{27}jk^{-1}$ [25] **Stacey** (1981)Ti average internal heating temperature,H(t)=internal heat generation at time t,

Q(t)=convective heat loss at time t.

Under perspective of Urey ratio Urey(1955,1956) for internal heating and surface heat –flux due to convective heat flow the accumulated thermal energy are balanced by Stacey (1981) energy conservation eqn.(15) Principles and mechanism further in the paper are to evaluate the time in approximation is summed up as total seismic energy U which is obtained by Equation (A) & (B).Seismic energy U is Sum of U_1&U_2 in the equation (15) ,U1 geothermal energy is obtained by the equation(15) up to level of detection of temperature T for which resistivity's increases at max. up to 1st stage finding steady state;[26] & further energy is consumed in generating stress, up to 4th stage of earthquake [27]Aden (1980) during the 2nd & 3rd stage of earthquakes for conducting materials decreases at min in the semiconductors & other igneous, metamorphic' and having no observable response for sandstone with porosity 24%[29]Beamish (1980), which Madden states in the equation.

Δj=ΔχH +Δ(NRM)+(PRM) for the rise in magnetic field due to stress.Electrokinetic effect of stress is experienced in the fig below by variation in resistivity different igneous metamorphic rocks against applied stress(axial).Here in the equation Δj= applied field , Δ χH change in susceptibility, ΔNRM remnant moment of magnetism & ΔPRM is acquired pressure: by Aden (1980) cited from Nut man et al (1976),Kean et al(1976) .It is remarkable that susceptibility decreases in parallel to compression axis and increases in perpendicular to compression axis;[30]Stacey,Johnson (1972) slightly by 1.11to 11.5×10^{4}

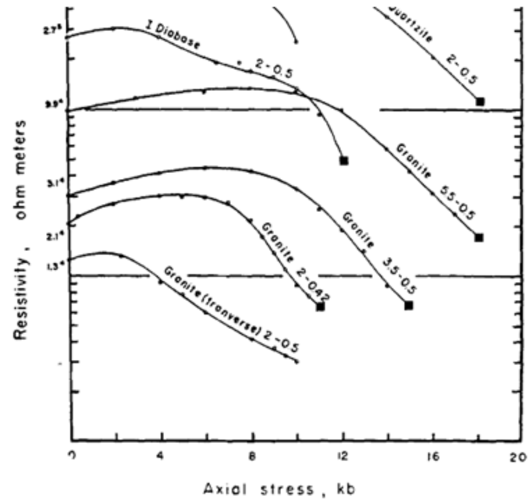

Fig. 2. Resistivity as a function of axial stress. The numbers after the rock name are the con and pore pressure in kilobars. The curves have been displaced vertically for convenience: 7.9^3 ı 7.9×10^3 ohm-m. All except the bottom curve are resistivity in the axial direction. Fracture oc at points noted by solid squares (after Brace and Orange, 1968).

Having U_1= geothermal energy.

Annual heat production due to heat flow in ergs /year courtesy: principles of geochemistry, [31](Brian Mason (1950)

Table 1

Rock type	sp.gr. (ρd)	Heat-flux ergs /g.yr	reference
Eclogite	3.30	?	
Basalt	3.20	72	Goldschimidt1949
Dolerite	3.10	72	Principles of geochemistry; Brian Mason1950
Diorite	3.00	90.5 ?	Same
Granite	2.67	235	Same& Anderson1979et al.
S.stone	1.98	?	Same
Limestone	2.0o	40.5 ?	Same
Shale	1.50		Same
Average		1.5 ×10-6cals/sqcm	

Source; Jacobs, Russell and Wilson physics& geology (New-York; McGraw Hill.1974).

Computation of U1 Energy

U_1=dE=J∫$e^{\Delta H+\Delta t}$.dt where U1 is the fraction of thermal energy turned into seismic energy to raise the temperature at T of the geomaterials under given dimension of area, J= Joule's constant.. Which is supported by the equation? (15) of Stacey (1981) in the eqn. of energy conservation? After integrating the equation (15)

$$\frac{CdT}{dt} = H(ti)—Q(t)$$

$$c[T]^2 = \int[H(t)\_Q(t)]dt\_ \quad (15)$$

$$1 = \Delta H.t + C \quad \text{----------eqn no (16)}$$

and $C[T_2\_T_1]$ =O+ C at time t=o

Where ΔH is total energy (geothermal obtained by internal heating &convective heat –flux accumulated in time t.during which T1 becomes T2 and remains constant up to time t Further increases in thermal energy is transformed into mechanical energy in another system-- Claudius (1989) The difference in T_2-T_1 =ΔT comes in the eqn (15) as

U_1= mcΔT for m= mass of given rocks as geomaterials.

For this table (1a) can be referred to feed the values of heat flux and heating rock materials nto the data..

Table 1 (a)

Types of heat	TW=10^{12}W	Reference
Internal heating ratio	.87	Jaupart et al(2007)
Global heat flux	46TW	Pallock et al.(1993)
Oceanic Heat –flux	32TW	Jaupart et al..(2007)
Continental Heat-flux	14TW	Lybsskya&Korenaga(2007)
BSE Heat –flux	14TW	Rudrickand Gao(2003)
CC Heat production	7.5 TW.	Rudrick &Gao(2003)
Convective heat-flux	36.5TW	Pallock et al. (1993)
Convective Urey ratio	.23	Korenaga(2007)

Secular cooling Rate 124
Source -Korenaga, J Seismol(2007): Urey Ratio & Thermal Budget

2. Methodology

Computation of U2 in the eqn $U=U_1+U_2$ ___(18)
U_2=stress× .volume change
= U─U_1, = [Prescribed seismic energy for asked magnitude ─ J.× observed thermal energy up to the rise of temperature T_2 ie difference ofΔT stored by equation (A)and (B)][31];Jacobson,Waserberg(1979),O Nions et al.(1979) under perspective of Urey ratio. Urey (1955-56 a,b.) For the computation of U table 1b &1c are helpful. **Source-K.S.Thybaum& S.K. Nath(2008) Applied Geophysics .**

Table (1b)

Indian Events Magnitude in Mw	Area	Energy	Method	adopted	Ref.
1897shilong	Mw=8.1	Sqkm	dynescm	GCMT	
1950Assam	8.7	150	2.3×10^{24}	‘same	1,2
1869 Gachher	7.4	180	3.5×10^{22}	Same	2,1Blcham(2004)
1918 Shimaya	7.6	170	2.5×10^{23}	Same	1,2
1930Dhirbri	7.1	200	2.3×1023	Same	2,3

Source:GCMT;Gglobal Centroid Moment Tensor database, ISC Centre (USA

1) Blacham (2004)2.S.K.Nath (2008)3.Nandy (2001)

World example of earthquakes events with theirs magnitude & energy released in the given area.

Table 1 (c)

Events with year	Magnitude	Area in sqkm	Energy released In dynes –cm	Method	Ref.
Aleutian(1906)	8.-8.4	200	2.9×10^{29}	GCMT	1,2
Chilean(1906)	8-8.9		3.8×10^{28}		Kanamari& Stewart(1976)
N Zealand(1967)	5.1-7.5	300km	$\mathbf{2.9\times10^{27}}$		P.J.Stafford(2008)et.al
Michoacán(1985)	8.0		5hz		Anderson1986
Malaysia(1990)	8.0		$\mathbf{3.2\times10^{28}}$		
Iran (1992)			$\mathbf{1.2\times10^{27}}$		
Fayaum(1992)	5.9				
Michoacán Mexico (1943)	5-6		$\mathbf{2}\times10^{27}$		
Valperiere event (1985)	5-6	20-60km range Depth30-50km	2.8×10^{28}		Kanamarie(1977)
Godely river(1984)	6.5	30	3.9×10^{28}		P.J. Stafford et al(12008)

Source; 1.Gutenberg and Richter (1954), 2. Stephen (1907) .3, Rudolf & Tames (1907), 4. Abe (1981) Solov & Go (1984)5.:, S.K.Nath et al.(2008) Applied Geophysics Supplemented by.ISC Centre USA.To determine the value of U2 which is the subtracted part of U1 observed value obtained by the resistivity change method in the table2b from U seismic energy (Calculated) with the help of table 1b, 1c. They are converted into mechanical energy as to equalize U .In the equation. (18) U ═log E is taken from the equation (7),(8),(10) of Ignimerieri Botti,*E.V. Pasquale..M.A.Anasturn M.Vol.-119., 1980-81, Pageoph for the given mass of the rocks under observation in the given situ.

U2 is computed by subtraction of U1 observed in Joules transformed by thermal energy supplied by internal heating H(ti) & convective flux(t)at time t.: Korenaga (2007) by reaching the temperature T under perspective of calculation. This value (in Joule) as mechanical energy is the conversion of thermal energy in the equation.(A)and (B). of Anderson(1985) et al.in the paper of Korenaga(2007).

From the equation (15) Stacey (1981) et al. evaluation of time in approximate can be predicted to reach the released amount of thermal energy~U2 Conversion of Thermal energy into mechanical energy under reference of
σij,i+Eji Pi+f j =ρduj

$$\frac{A}{dt}$$

provides thermo mechanical and electrical energy conservation

Where, σij =1/2(EiPj-PiEj) is conservation of angular momentum and gives Cauchy stress. CS Upadhyaya andCVenkateshan (1997)

Table 2a

Mass of the earth	$6.0\times\mathbf{10}^{27}$ kg
Average sp gravity of the earth	$5.5\times kg/m^3$
Sp heat of the earth	$7\times10^{27} j/k^{-1}$ Stacey (1981)
Processing rate	$6.7\times10^{14} kga^{-1}$

Source: Principles of geochemistry, Brian Mason (1950-55), Korenaga et al(2007)

Determination of temperature rise on the basis of variation in resistivity's of the rocks under observation. Table for synthetic data.

Table 2b

Sl No	ρt	ρ0	$T_c=(\rho_t\_\rho_0)/\alpha$ tempT_s.	T_c	Average	
1	12.5 Ohmmt	12.00 ohmmt	20.56	20.40	20.48	Rise in temp
2	12.85	12.50	15.5(35)	15.00	15.25	Lowering
3	13.5	13.00	20(.50)	20.00	20.25	Rise
4	13.95	13.54	18(.44)	18.00	18.22	**Lowering**
5	14.50	14.00	20(.50)	19.50	19.85	Rise
5	14.95	14.50	18.0(.45)	18.00	18.25	Lowering
6	15.50	15.00	18.5(.)50	18.00	18.25	Const
7	16.02	15.50	.19(48)	18.50	18.22	Const
8	17.00	16.50	.20(50)	19.50	19.025	Rise
9	17.50	16.50	.35(90)	34.05	34.48	Rise
					$\frac{\sum T_s+T_c}{2}$	

α=.025per ^{0}C at 20 ^{0}C for the geo materials: source Keller and Frischknecht,(1966).

Table 1 (d): Average heat production values &caln packing on the basis of radioactive heat flow for k decay.

A

Rock type	Densityρd	HGU	$\mu w/m^3$	$K\times10^{-2}$ mole$^{/cm}$
Granite	2.67	7.0	2.92	4.70
Granodiorite	2.7	3.6	1.50	1
Diorite	2.82	2.7	1.13	5.20
Gabbro	2.98	1.0	.417	5.40
Eclogite	3.30	.15	.063	6.14

Where ρd=density, A=heat flow due to radio activity,
Source: Rybach(1973) &Bunted Barth(1975) J of applied geophysics.

3. Discussion

For equation (15) we get increase in remains constant in rise of temp Clausius(1860)rise is consumed in conversion into mechanical energy supplementing seismic energy . T temperature remains constant till U2 is achieved. As t →∞U1→o in the equation (18)

U=U1+U2 ,Thus time elapsed during the enhancement of energy after reaching constant value of T can be approximated again balancing the U2 value in terms of thermal energy obtained by equation(15):Stacey (1981)in the perspective of Interior heating of continents and mantle with accumulation of Heat flux Anderson(1985)et al This fact is supported by the equation already mentioned in introduction as $\rho_t=\rho_0\{1+\alpha T)$:rein et al(1979) which affects the resistivity's of the geomaterials by way of energy rise in U1This fluctuation in the electrical properties of the geomaterials have been observed during the 2nd & 3rd stage of earthquake and ground motion at the area under observation EIliby(1980),Meyer(1976) ,Bolt(1988).

Relation ship between resistivity &temperature; of the geomaterials:
V/R=n.e.Avd

$$\frac{El}{\rho.l/A} = \frac{neAeE\,\rho}{m} \qquad \text{------------equation *(18)}$$

$$1\ /\ \rho\text{— -}=ne^2\Gamma/m$$

Or

$$\rho = \frac{-m}{ne^2\,\Gamma} \qquad \text{------------------(19)}$$

Where Γ is the relaxation time of electron drift ρ is the resistivity of the geomaterials.On the platform of thermodynamics' energy conservation principle Brian Mason (1950)-principles of geochemistry' under perspective of thermal budget & Urey ratio (Urey1956) by computing the temperature on fluctuation of electrical properties provides a reliable& acceptable technique for approximating predictory time With the known value of T or Δθ rise in temperature of the system under observation eqn.

$$P_{t.} = \frac{m}{n_0 e^{Eg/KT)} e^2\Gamma} \qquad \text{------------ (20)}$$

In the eqn no (20)the value of electrons (n)increases with the rise in temperature Determined value of n & relaxation time Γ can be estimated for bringing T=Δθ=0 or equilibrium time elapsed ~time to reach at temperature T .Time determined thus must be qualifying the time calculated by the law of Newton's Cooling rate as

$$\frac{dQ}{Dt} = \text{-—}k(\theta_2-\theta_1)=K(T2-T_1)\text{----------------(21)}$$

Kis the power const. depending upon the surface of the body areaand nature of the body. Since $dQ=mc\ d(T_2-T_1)$ implies the rate of cooling, so that,

$$\frac{T2}{T_2-T_1} = -\frac{k\,dt}{mc}$$

Implies,

$$Log(T_2-T_1)= -k't+C\_\_\_\_\_\_\_\_\_\_\_\_\_(22)$$

after integrating the relation
or, $e^{-kt+c}=(T_2-T_1)$
or, $T_2=T1+e^{-k't}+C$
$= T_1+C'.e^{-kt}$---------------- (23)

Where $C'=e^{c.}$ value of c on the exp by puttingT1, T2& K time (t)allotted which will be similar as obtained by the equation (13) to (!8) in the resistivity's determination in context with the U1 value. Once T2 is fixed or the time t is achieved to attain the magnitude level =>5to 6, average increases in temp. as Δθ=T is estimated this value incorporates with energy stored by heat-flow and radioactive heat-flow.:Laclsaus Rybach (1978-79) vol.-117.pageoph.

Again in the panorama of seismic wave tomography (lopo Boschi (2007) enhancement in the seismic energy is influenced by the radioactive heat flow(A)& is increased with decrease in Vp,; Rikitake (1976) et al.

With the change in Vp/Vs ratio as increase, is the reflective of decrease in the heat-flow & thus rise in temperature of the system under observation. Sorensen (2000) et al & thus change in resistivity's of the geomaterials; Rein et al (1979).

Case study of UK earthquake (1990) may be referred as the part of evidentiary support to the Facts lying in the paper. Data on resistivity's decrease with the increase of seismic moment and thus energy level and hence rise in the temperature of the rock system under observation with the equation $\rho_t = \rho_{0(1+\alpha T)}$Rein et.al(1979) prior to the 2nd and 3rd stage of quake:Tsenji,Rikitake (1976)by Chris gray (2007)Rate of rise in the temperature assimilating the decrease in the resistivity of the geomaterials or the selected materials like nicrome or quartz like semiconductors up to steady state.(Kelvin 1863,Sorenson , and Anderson (1980).

Table shows the energy generated during historic events of earthquake with their magnitude & Mw moment prescribed along with the a and b values and calculated values of energy released during the prescribed magnitude.

Table 2 (c):
α=—β(M)+ Log E Dynes CM\`
a-b(M)/β

Events	Energy(ergs)	**A ρ⁻ohm-mt**	B Θ	α	**β**	logE	a-b(M)/β	Method	**Remark**
1990	**2.6×10^{24}**	15.5	12.5..		.68			Aki(1965)	M=5.9
1992	**2.6×10^{24}**	15.6	12.9		.78			Do	M=5.2.
1994	3.5×10^{23}	**16.5.**	13.5		.80			Do	M=4.8
1995	2.6×10^{23}	16.8	13.9		.90			Do	M=4.5
1997	1.8×10^{23}	**17.2**	14.0		.95			Do	M=4.2
1999	1.3×10^{23}	17.8	14.0		**.89?**			Do	M=4.0
2002	2.9×10^{25}	15.0	12.5		.678			Aki(1965)	M=6.1

Table of the data on decrease of resistivity's against the temperature; for Case of Columbia (7mw on 9th Feb'2013

Table 3a see appendix

4. Conclusion

1. Well planned selected site under observation if is equipped with required appliances as mentioned in the article can be suitable and reliable technique in the prediction of ground shaking considerable time of alarm starting from 5 to several hours to adopt mitigation in the hard prone area **.**

1. Further investigation & works on this line may be fruitful tool in the precautionary mitigation.

2. The vulnerability in case of fault zone and epicentral area can be inferred with the use of this technique:

3. In the mitigation of PSHAas in ref the tool may prove fruitful.

4. Once the appliance as prescribed to determine the resistivity change in the seismological laboratory monitoring the resistivity variation may cover the EEp Tenusiji Rikitakea(1980)

Using square array of electrodes under perspective of

$$\rho a = \frac{\rho_m}{2 - (2)^{1/2}} - \left(\frac{2}{1+N^2-(1+\cos\theta)^{1/2}}\right) - \left(\frac{1}{2+N^2-1(1+\cos 2\theta)^{/1}}\right) - \left(\frac{1}{1+N^2-(1-\sin 2\theta)^{1/2}}\right)$$

Haberyam and wetereg (1967)[7]

5. Failure behavior of the rocks affected by varying condition of temperature & pressure condition of deformation .Kyoo Mogi in his treaty Rock fracture (Mogi ;67) supports: stress may sometimes have to be applied at very slow rate to simulate the tectonic condition.[9]

6. Stress strain effects on the local Magnetic field in the equation

Δj= Δℵ H+Δ(NRM)+PRM----------------------- (1)[10]

Where Δℵ=change in susceptibility, ΔJ=applied field and PRM= acquired pressure& NRM Is the remnant moment (change); has been observed susceptibility parallel to compression axis increases slightly.

7. (a) Stress –resistivity of magnetic susceptibility behavior; [11] values 1.11 to 11.5×10^{-4}/bar.

(b) Fracture stress of 1 to 2/3 rd corresponds to decrease in resistivity of rocks due to increase in the rocks' pore pressure& no of voids developed ie no of cracks development in one set of dilatancy(orange 1968).

(i) Sandstone (~3%) porosity behaves like igneous & metamorphic rocks

Permeability increase 3 fold in and are of >50%fracture.stress in granite and sandstone: Brace (1978).Which is obvious in the Russian field example as case for resistivity variation prior to **earthquake** [12.]

8. dE/dx has been observed typically.3%<1mv/km and almost in 400 observations for 19 **different sites Rikitake (1976) found using the formula;**

Log_{10} T=.6M_1.01: low stress-level changes resistivity by 10% decrease For the circle of epicenter radius could be determined

$r=10^{0.43M\ km}$

$=10^{(0.51M-2.27)}km$[13]

9. (a) Nur (1975) considers that" Fault creep precedes fracture then the dilatants volume can either increase with the cracks development or decrease with time": Stress level measurement[14] .

(b) The external stresses from neighboring & remote regions truncated towards the intersection point it becomes kernel(Tan et al(1987) in the paper of N Ramanujam(2006) dealing with 'Azimuthally square array resistivity measurement at Kerala'

(c) The presence of cataclastic in the fault zone may be another cause for the development of low resistivity zone (Scholez et al (1993)[15]

(d) Zhao Yu lin Quian Fu Ye observed linear compression strain of shallow layer in and around the epicenter area in order of 3.10 5 2 months prior to Tangshan (china) Earthquake 1976.[16]

10. 'Relationship between temporal variation in electrical resistivity and occurrence of earthquake of 30 Sept. 1993 Latur (India)[16] have measured the length of fault incurred using the equation M= 3.3+2.1Log L , that validates the concept laid in the paper of author.

(b) Degree of anisotropy of resistivity of material (Feng2004)[17] have tried to elucidate the stress direction on the basis of + ve or — ve nature of resistivity change and degree of anisotropies' with the equation.

$$S= 1/n \sum_{r=1}^{n} [\{\frac{\rho_{NS}}{\rho_{EW}}\} =1] .10^4 \quad n=6 \text{ ---------(i)}$$

$$S= [\{\frac{\rho EW}{\rho NS} -1\}]\times.10^4 \quad \text{---------------(ii)}$$

For ρ_{NS} = ρ_{EW} we have S= 0 that their materials are isotropic and the resistivity changes uniformly. Greater the difference in S values higher the anisotropy (even for the negative values) and good chance of stress accumulation preparing for the earthquakes.

12. T Mogi et al[2004][18] in his paper: "Geo electric potential difference monitoring in southern Sumatra Co seismic changes " deals how the variation in the electrical resistivity's of the geomaterials on an area prior to the event prepares the moment for the ezrthqukes.by 10-100 mv decrease in a fortnight.

13. Time resolved study of charge generation propagation in the igneous rocks resistivity, ground potential changes and electrical luminous signal (EM)electromagnetism change preceding or accompanying EQ when the impact of stress is allowed at range of9to 1.5 km /s: detailed by Freund Friedman (2000)[19].

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Appendix

Table 3: Shows the variation and decrease of resistivity prior to the event of Colombia 7mw on 9th Feb;13

Date	TEC %	Lat	Long	Proton flux	E-Flux	Tindex	P(resistivity
14.01.13	60-70	5-8N	45-50w	Rise indays	Lower10^4 Amd10^2	Elevates By20u	Decreae 15.0
18/1/13	57%	"'	Do	rise	Decrease im10^4,10^2	Depressed 20	Increase 15.5
22/1/13	50%	'"	'"	decrease	Increasei in10^4·10^2	Elevates By20u	15.0
24/1/13	50-60%	'"	'"	increase	Lowerin 10^4·10^2	20u	14.5
25/1/13		"'	'"	do	do	do	14.0
26/1/13	60%	'"	'"	'	increase	"	14.0
27/1/13	60%	'do	'"	'	Lowers In10^4·10^2	"	14.0
28/1/13	60%	'"	'"	'	do	"	13.5
4.02.13	65	"	"	Decrease	Increae In10^4,10^2	"	13.0
5.02.13	65	"	"	Increase	decrease	"	13.0
6.02.13	70	"	"	do	"	"	12.5
7.2.13	70	do	do	do	do	do	12

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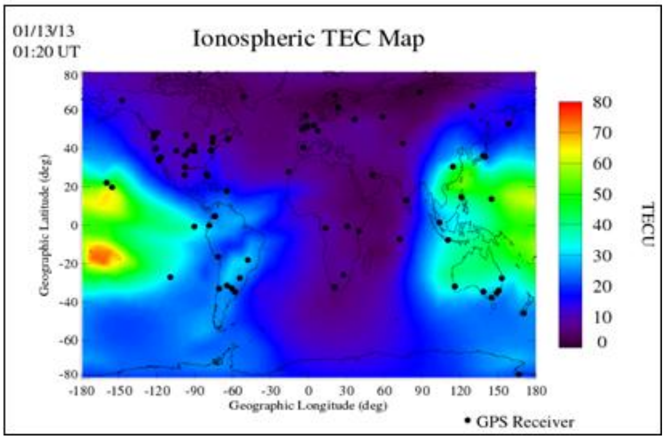


Figure 1: Below states the Tec variation on 13.01.13:image JPL NASA

Figure below shows the TEC rise on 8Feb On Global map over Columbia: Image IPS Australia

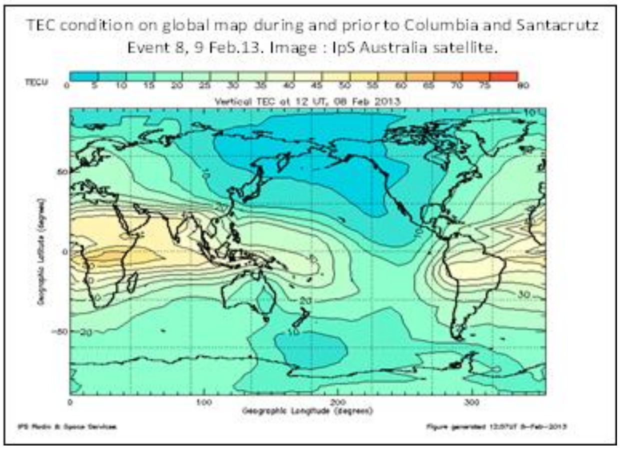


Figure 2: TEC on 2201.13

Fig shows the variation of Electron flux on22.01.13 on global map prior the event: image NOAA.

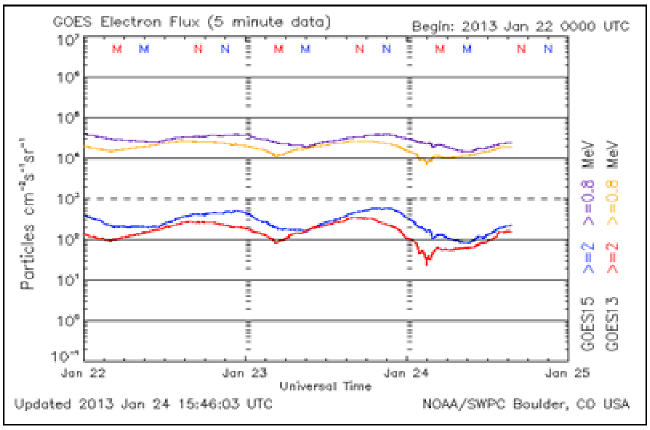


Figure 3

Fig below states the variation of Electron flux on 5thFeb on global map prior Event :Image NOAA

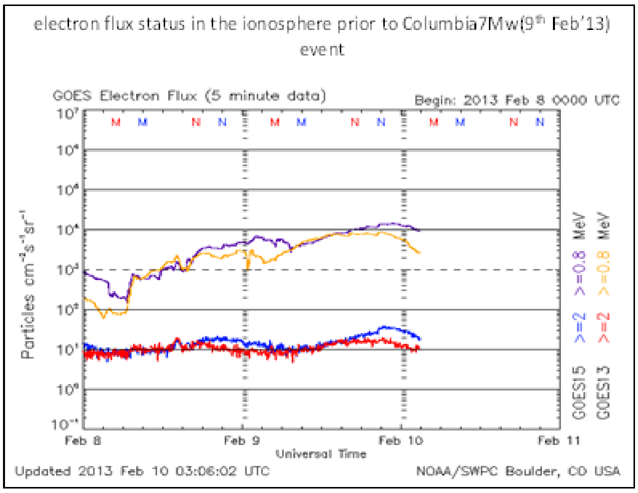
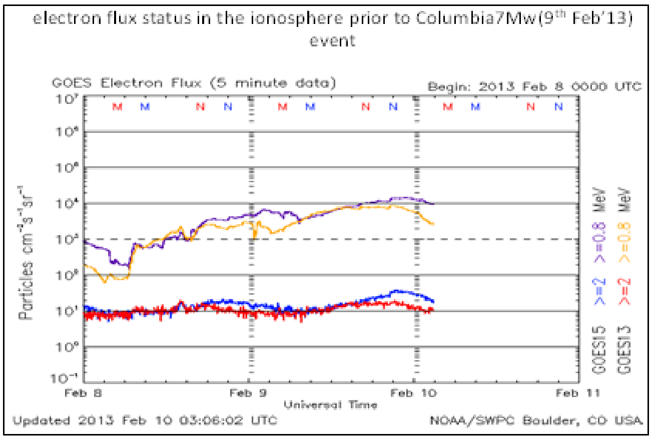


Figure 5: Sates the variation of electron flux on8th Feb'13 priot to the event of Columbia7Mw



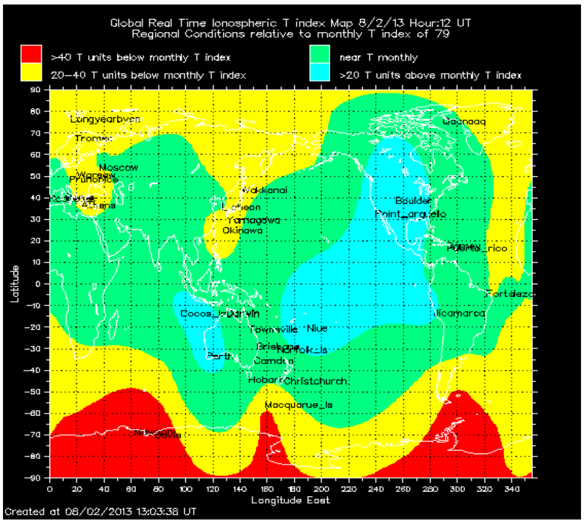


Figure 5: States the T index status on global map on Feb8 prior to the event of Columbia 7Mw on 9thFeb'13 Courtsey :Image IPS Australia.