Conceptualization of role of shearing stress in understanding earthquake mechanism

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Abstract: Approximately at 1000km depth in Mantle, enhanced thermal energy (probably generated due to influence of gravitational force associated with astrophysical sources) leads to shearing stress. The maximum shearing stress outbreaks into two possible (at least) components: tangential and radial. The tangential always exceeds the radial at least by 120 Mpa. Such an enhancement results in propagation of sufficient amount of seismic energy, through the overlying stratum, away from the initiation point of shearing stress. The combined influence of internal friction (Columbian friction μ) of overlying stratum, temporal extra-terrestrial gravitational pull (viz. by moon) and acceptable creep rate of straining stratum exhibit a drop. From such an activity it is probably possible to detect the nature of tangential and radial components’ additive or subtractive effects on magnitude and location of a seismic activity. We advocate that knowledge of such an inter relationship between earth system processes would help in better understanding of the genesis of intraplate seismicity and landslides activity [as in Brazilian landslide-14th Jan’11]. A comprehensive study on this inter relationship between various processes may probably bridge gaps in our understanding of earthquake resultant activities and lead to area specific medium level forecasting, a positive development from the point of earthquake prediction.

Keywords: Tangential stress, Radial stress component, Columbian friction coefficient, Intraplate seismicity, gravitational pull.

Introduction

Classics of brittle nature of rocks inspire to investigate the mechanism laid and processes involved in the propagation of stress flow through the stratum rocks. Factors on which the processes depend always entice us to establish the governing concept. Due to dynamic behaviour of processes undergoing into and around the globe, heterogeneity of Characters (specially Physico-chemical) pose difficult moment for stable concept to frame in dealing with responsible processes like of seismicity. Experimental observations on the rocks specimen in lab and situ by T. Mogi(1960), Z Suzuki(1970), Orange and Brace et al(1984) {for dialatancy in the rocks} flashes light for opening the stress-strain concept responsible for the seismicity and related phenomenon. Generation of stress in the mantle in access to equilibrium is expected endothermic and astrophysical both. Stress in form of thermal and mechanical if is detected at exact point of initiation and its nature to outflow and factors responsible to orient them it becomes easier for explaining the cause of seismicity and thus in bridging the gap of information for predictive theory. Culmination of Mohr’s Mohr (1882) concept for stress envelopes and circle of stress for applied shearing stress on the rocks and its nature of strain with Sayer and Sen (1990) FEM model for thermo elastic and plastic characters and its concluding result detailing tangential and radial behaviour of stress helps in finding the solution to our problem.

Otto Mohrs’ equation of stress acting on the plane of rock is supposed to associate in the direction of fracture plane as shearing and perpendicular to it as normal stress. The simulation of tangential stress can be simulated with the tangential and normal stress in the FEM model of Sayer and Sen (1990). Earlier in the paper by U.P. Verma(2011) the simulation of force and its moment due to reaction force of Gravitational pull of celestial bodies on the globe could have produced satisfactory result for explaining and forecasting the seismicity at an area in magnitude and direction. Mission of the paper is to elaborate and flash the light on the hidden concept in previous paper.

Various lab experiments of stress behaviour on the rocks of varying physical and chemical characters is governed by the equations of (Otto Mohr, 1882)

\[ \sigma_1 - \sigma_3 = \sigma_1 + \sigma_3 \]
\[ \sigma_1 - \sigma_3 = \eta \cos 2\theta \]
\[ \sigma_1 - \sigma_3 = \eta \sin 2\theta \]

From Newton’s 3rd law of action (Gravitational pull) and reaction F due to this force in the globe \( F(R-x)\cos \theta + F(R-x)\sin \theta \): a summation of components for the reaction force F separately can be simulated to...
above equations in the given cone volume of globe. This simulation is added by the culmination of stress of tangential and radial nature discussed for the FEM mode by MatinSayer and F.Sen(1990). By proceeding in the base of concept of thermoplastic and thermo elastic model tested at 60°C to 120°C of temperature range in the lab experiment results in fruitful equations. That describes the values of tangential stress being 120 Mpa, Often greater than the radial stress on various layer of the composite FEM. This fact is used in the simulating the shearing and normal stress as into tangential and radial stress. Data of events acquired if are analysed and set minutely keeping the pace with creep rate internal friction and to that of available stress energy generated for a specific sequence one can expect the seismicity in magnitude and direction at a particular depth. Fig below chemately explains the formation of stress circle and tangential plus radial stress thereof at right angle to each other.

Our globe is itself spherical model of heterogeneous composition varying from steel to talk like soft material. Underconstrained parameterized condition the failure behaviour of rocks constituting the overlying stratum sets up the initiation of stress progressing in tangential and Radial direction as simulated by Mohr’s(Mohr’s1882) direction of shearing and normal stresses.

The figure below explains the stress produced at 60°C on inner and outer each stratum layerwhich is controlled by the equations.

**Principle and Mechanism**

1. Entire mechanism of stress generation is disturbance in the equilibrium of the thermal stress existing prior to any event. At the depth of approximately1000km i.e. interface of Up-lower mantle enhancement in stress (thermal) transferred due to gravitational pull due to astrophysical sources like sun and moon on the earth.3


3. Mohrs’ envelopes of stress applied on the solid rocks supports the mechanism to estimate the magnitude and direction of stress and subsequent failure behaviour to expect,

4. Determination of sign of stress components, direction and magnitude is the subject of principle best obtained by Sayer and Senmodel16 which states the nature of steel fibre at 60°C to 120°C.
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Fig. 4 Elastic strain on the stratum produced

Strain components for the orthotropic materials can be written as

\[ \epsilon_x = \alpha_1 \sigma_x + \alpha_{12} \sigma_y + \alpha_T \]
\[ \epsilon_y = \alpha_2 \sigma_x + \alpha_{21} \sigma_y + \alpha_T \]
\[ \gamma_{xy} = \alpha_{66} T + \alpha_{xy} T \]

Shear stress value can be obtained with the differentiation of above equation no 1

\[ \frac{\partial \sigma_{xy}}{\partial x} + \frac{\partial \sigma_{xy}}{\partial y} = -\frac{\partial \epsilon_x}{\partial x} \]

As for the equivalent shear stress in the direction of fibre or tangential can be written as

\[ \sigma_{xy} = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_{xy}^2} \]

Residual stress due to the superposition of the elastic stresses and plastic stresses provides the residual stress values as,

\[ (\Sigma_r)_{xy} = (\sigma_r)_{xy} - (\sigma_e)_{xy} \]

Mohr’s concept of stress-strain relationship stating stresscomponents and their magnitudes:

Fig 5 explains possible fracture plane at \( \theta = 45 - \phi / 2 \) and \( 45 + \phi / 2 \) which is hereat 29° and 61° for constrained parameters taking internal friction \( \mu \) as .653 for rock stratum

Simulation of Mohr’s equation with the Sen and Sayer’s equation

We can estimate and understand the radial and tangential components are equivalent respectively to the Shearing and normal stresses in the coplanar (fracture) plane produced by Mohr’s Concept as below:

\[ Fg \sin(R-x) = F' \sin\theta_1 (R-x) + F' \cos\theta_1 (R-x) \]

has two parts

\[ F' \sin\theta_1 (R-x) = \sigma_n = (\sigma_1 + \sigma_3) / 2 + (\sigma_1 - \sigma_3) / 2 \cos^2 \theta \]  
\[ F' \cos\theta_1 (R-x) = \sigma_s = (\sigma_1 - \sigma_3) / 2 \cos^2 \theta \]

Equations a and b both are equitable with the equations 3, 4 and 5 thus opening the scope for the concept building in the paper.

Methodology

To exhibit the concept development based on the principles and mechanism stated we adopt following steps in the methodology.

- Acquire the data on celestial positions viz distances of Sun, Moon etc. w.r.t. the globe. And their masses for the calculation of gravitational pull on the globe at certain time as calculated in the previous paper by the author.
- Transfer the same pull into the equivalent energy taking moment about any point (point of ecliptic fall) and distribute the same for proportionate amount of seismic energy in Mw which a particular overlying stratum rocks at certain depth can withstand under constrained parameters. Here constraints are internal friction of different rocks constituting the stratum, rigidity, resistivity, conductivity, dailatancy, susceptibility, thermal capacity, porosity, and chemical characters too.
- Treat the calculated amount of gravitational energy transferring into equivalent seismic energy in Mw distribute the same into detected point of reactions for the pocket of stress to be initiated at. These points of reaction are determined as in the previous paper of author.
- Allocating the point of reaction on the globe allow the available thermal or mechanical stress in pocket to be fractionated in to radial and
tangential direction with the plane of fracture assumed based on Mohr's concept. Under constrained parameters estimate the outbreak of stress energy in proportion to the yield strength and other parameters. Progress of stress either in radial or in tangential plane of fracture in the insuring phase of events should be balanced in proportionate to seismic energy allotted just to peer out of initiation point. Amount and nature (+or-) of residual stress in the reservoir must be detected and determined so as to find the resultant superposition of additive or subtractive effect on any point of intersection on the globe by the traversing stress components. After determination of all these characters of the insurred stress at any point on globe the depth and magnitude can be estimated at. The time of arrival of stress at the considered point next to the previous event with permissible creep rate may be estimated. Data are collected from the Usgs events for 2011 and updated data of events till the date. Plotting of event starts first with approaching moment of eclipse over the region.

Data Collection: For the placement of all information’s regarding events magnitude, latitude longitude and duration are plotted in the table of events. Their respective energy are calculated in terms of Joule and entered into Table 2. We place the estimated amount of gravitational energy transferred in to the seismic energy in joule.

**Showing the energy generation owing to ecliptic fall of Jan and May2012**

<table>
<thead>
<tr>
<th>Date</th>
<th>Distance Perihelion Km²</th>
<th>Mass of the Celestial in Kg Mₜ + ᴹₚ</th>
<th>Distance of Aphelion Km²</th>
<th>G=6.667 x 10⁻¹¹ NM²/kg²</th>
<th>F= [G M₁ M₂ / R²] Newton</th>
<th>Energy (Joule)</th>
<th>Moment Equivalent (Considerin g μ = .653)</th>
<th>Total no of EQs Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-01-12</td>
<td>2.1586 x 10¹⁶</td>
<td>2.1 x 10³¹</td>
<td>2.27x 10¹⁶</td>
<td>Do</td>
<td>84.7x 10²⁷</td>
<td>4.32x 10³¹</td>
<td>2.45x 10³¹</td>
<td>7.8 for 90s</td>
</tr>
<tr>
<td>21-05-12</td>
<td>-----</td>
<td>2.1 x 10³¹</td>
<td>2.297x 10¹⁶</td>
<td>Do</td>
<td>37.26x 10²⁷</td>
<td>1.77x 10³²</td>
<td>1.16x 10³¹</td>
<td>5-6for90s</td>
</tr>
</tbody>
</table>

**Acquisition of data: Tabulation of observed events and their energy.**

<table>
<thead>
<tr>
<th>Date of events</th>
<th>Observed temp</th>
<th>φR at 32 degree</th>
<th>σₚ Tangential stress (in J/V) at 61 degree</th>
<th>σₜ radial stress in J/V at 29 degree</th>
<th>ϵ.R strain Rate</th>
<th>ϵ.T Tangential Rate</th>
<th>Residual stress in J/V</th>
<th>Yield Strength in X/Y</th>
<th>Date Of next event (expected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>07-02-12 Philippines</td>
<td>Taken to be 500-120K depth wise</td>
<td>0.651</td>
<td>6.8Mw = 4.5x 10¹⁵</td>
<td>3.2x 10¹⁵</td>
<td>10⁻¹¹ mmmps *</td>
<td>10⁻¹¹ mmmps *</td>
<td>2.5x 10⁻⁵Mpa</td>
<td>X=14.0Mpa Y=5.4Mpa for 30-50mm Radii(comp.disc)#</td>
<td>14-02-12 Japan 6-6.2Mw</td>
</tr>
<tr>
<td>14-02-12 Japan</td>
<td>450K</td>
<td>Do</td>
<td>6.0 Mw = 1.5x 10¹⁴</td>
<td>3x 10¹⁴</td>
<td>10⁻¹⁰ mmmps *</td>
<td>10⁻¹⁰ mmmps *</td>
<td>2.8x 10⁻⁵Mpa</td>
<td>Do</td>
<td>22-02-12 Northern India 6.2 Mw</td>
</tr>
<tr>
<td>20-02-12 India</td>
<td>........</td>
<td>Do</td>
<td>5.0 Mw = 2.5x 10¹³</td>
<td>*</td>
<td>10⁻⁶ mmmps #</td>
<td>10⁻⁶ mmmps #</td>
<td>4.8x 10⁻⁴Mpa</td>
<td>Do</td>
<td>NPG 6.5 Mw by 25-03-12</td>
</tr>
</tbody>
</table>

International Journal of Advanced Structures and Geotechnical Engineering
ISSN 2319-5347, Vol. 01, No. 02, October 2012, pp 33-41
### Analysis of Data Acquired

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Magnitude</th>
<th>Pressure</th>
<th>Stress</th>
<th>Date</th>
<th>Location</th>
<th>Magnitude</th>
<th>Pressure</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-03-12</td>
<td>Oxaca (Mexico)</td>
<td>7.6 Mw</td>
<td>$2.5 \times 10^{16}$</td>
<td>$1.9 \times 10^{15}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>2.3 x $10^{23}$ MPa</td>
<td>Do</td>
<td>20-04-12</td>
<td>Chile &amp; 7.2 Mw by Tan. &amp; NPG by Ra 6-7 Mw</td>
</tr>
<tr>
<td>21-03-12</td>
<td>NGP Interference of Ra &amp; T</td>
<td>6.7 Mw</td>
<td>$1.5 \times 10^{15}$</td>
<td>$2.4 \times 10^{14}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>3.5 x $10^{22}$ MPa</td>
<td>Do</td>
<td>Chile 6-7 Mw by 20-04 Tonga fizzly 6-6.5 by 30-04-12</td>
<td></td>
</tr>
<tr>
<td>25-03-12</td>
<td>Chile</td>
<td>7.2 Mw</td>
<td>$2.3 \times 10^{16}$</td>
<td>$2.1 \times 10^{15}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>4.5 x $10^{23}$ MPa</td>
<td>Do</td>
<td>India 5-6 Mw 20-04-12 Aus. 3-4 Mw</td>
<td></td>
</tr>
<tr>
<td>8-04-12</td>
<td>Mexico</td>
<td>6.0 Mw</td>
<td>$1.4 \times 10^{14}$</td>
<td>$2.1 \times 10^{13}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>3.5 x $10^{22}$ MPa</td>
<td>Do</td>
<td>Do + Tonga By 30</td>
<td></td>
</tr>
<tr>
<td>9-04-12</td>
<td>Drake Island</td>
<td>5.8 Mw</td>
<td>$3.2 \times 10^{13}$</td>
<td>$2.5 \times 10^{13}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>2.5 x $10^{20}$ MPa</td>
<td>Do</td>
<td>Tonga and Indonesia by 30-04 6 and 7 Mw</td>
<td></td>
</tr>
<tr>
<td>11-04-12</td>
<td>Indonesia</td>
<td>8.4 Mw</td>
<td>$5.4 \times 10^{16}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>2.5 x $10^{18}$ MPa</td>
<td>Do</td>
<td>India &amp; western Australia of 5-6 Mw by 20-05-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-04-12</td>
<td>Indonesia</td>
<td>6.0 Mw</td>
<td>$1.5 \times 10^{14}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>3.0 x $10^{17}$ MPa</td>
<td>Do</td>
<td>After sock of mild magnitude are expected in Pacific for the entire May &amp; June month</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29-04-12</td>
<td>Tonga</td>
<td>6.2 Mw</td>
<td>$1.8 \times 10^{14}$</td>
<td>$10^{-6}$ mm/s #</td>
<td>2.2 x $10^{19}$ MPa</td>
<td>Do</td>
<td>20-05-12</td>
<td>India 5.0 Mw = 2.5 x $10^{13}$</td>
<td></td>
</tr>
</tbody>
</table>

**Analysis of Data Acquired**

Fig-8 Sequence of events supports the facts of paper under discussion. Fig and data supplied by Australian Government.
Concept building

Following facts after discussion of principles and basing the presented data in support can be summarized as the concepts we can develop.

1. Reaction point just at 180° from the gravitational pull on the globe due to astrophysical sources like Sun, moon and other celestial bodies can be expected to interact at the interface of Up-lower Mantle at 10000 km from the crustal surface.
2. Maximum principal stress, and min. stress $\sigma_2$ have their resolution as shearing stress $\sigma_s$ and normal stress $\sigma_n$ are interacting on the fracture pane at right angle to each other.
3. Amount of differential $\sigma_1 - \sigma_2$ is the measure of stress drop in the constrained depth proportionate to the yield strength, Columbian friction coefficient $\mu$, clipeiran slope $d\Delta T$ and thermal conductivity, resistivity and other mechanical properties of the overlying stratum rocks.
4. Enhancement in the thermal stress is proportion to the magnitude of seismic energy transferred (obtained) from gravitational pull on the globe at the concerning the ecliptic phase.
5. The direction of the stress components are at $\theta - \phi/2$ and $\phi/2$ according to fracture direction concluded by Mohr’s (Mohr’s1882) concept for rock mechanics. Value of $\theta = 45^\circ$ and $\phi/2 = 32^\circ$ for the maximum sheared fracture and internal friction angle of average rocks gives the direction $29^\circ$ and $61^\circ$ for radial and tangential direction of stress initiation.
6. On the basis of FEM model result Sen and Sayer (1990) the tangential stress is always greater by 120 Mpa than the radial stress. Hence shearing stress in most cases precedes the radial or normal stress $\sigma_n$.
7. Interaction of stress with overlying stratum rocks behaves firstly elastically then thermoplastic alloyobeying the stress-strain rules.
8. The components of stresses are either positive or negative in sign depending upon the progressing direction on the stratum for both the tangential and radial direction.
9. Generally tangential stress is assigned to the first out breaking stress drop on the globe keeping pace with the yield strength of the stratum rocks.
   (a) First outbreak as foreshock initiates at deep focus depth.
   (b) Next outbreak initiates shallow depth sequence responding the available residual stress magnitude. © Detection of sign confirmation as positive the outbreak is continuous in the next sequence and incase of negative sign it opposes the entropy direction and landslide may take place. Same has occurred in Brazil on 14th January 2011.
10. Tangential stress outbreaks till the residual stress continue in the reservoir.
11. Radial stress gets chance to initiate just after the 2nd or the third outbreak of tangential with full swing of course even causing landslides and intraplate seismicity.
12. Progress of radial stress component may alternate the tangential outbreak by one or 2 events constraining the available parameters and stress energy.
13. On the tangential or radial line of progressive stress the prediction of further event can be made.
14. Confirmation of all the enumerated concepts formed can be verified with TEC data Pattern over any region and any real time lapse.

Fig. 10 represents the alignment of events in the sequence as aligning into the radia and tangential stress components direction map has been taken from the GPS and GSRM from the tectonic plates map Almindger (2004) and Zha and Zjung(2000)

15. The time and space lapse for stress component depends on the parameters like depth, yield strength, internal friction and available stress density of stratum and permissible creep rate for strain.
16. Superposition or interference of two stresses of same or different kinds and nature may yield according effect.
17. Same kind and same nature from two initiation point may enhance the magnitude of stress as in case of Indonesia*.3Mw on 11th April 2012 whereas opposite kind may subtract the magnitude and direction of progress and thus deepening the outbreak as in case of Tonga6.0Mw at 129 km on 28th April 2012.
18. Generally consumption stress in the sequence of outbreaks continues for the aftershock outbreak seismicity.
19. Prediction for the next outbreak is possible in time magnitude and space depends on calculation of available stress energy, nature and kind of pattern of superposition and parameters constraints as Most of events of 2011 and this year 2012 specially Hnshu 6.0Mw on 14th Feb and 14th April 2012 and Tonga 6.0m on 28th April

Courtesy: IPS Australia by P Hollis, Watts Data and figure concludes and depicts the verification of stress tangential progressing towards Tonga and Fiji.

International Journal of Advanced Structures and Geotechnical Engineering
ISSN 2319-5347, Vol. 01, No. 02, October 2012, pp 33-41
initiating from the point of reaction formed at Saudi Arabia through India and Indonesia.

Conclusion
1. With the application of data acquired and numerical modelling made as a result of culmination of FEM model by F. Sen. and Matien Sayer(1990) to the Mohr’s concept of Stress strain relationship provides the new concept building formulae in the seismicity monitoring and earthquake prediction. The Radial and Tangential stress value formulated by Sen and Sayer (1990) can be simulated
2. With the stress behaviour on the overlying stratum rocks by Mohr’s f Stress drop concept and Stress components into shearing or tangential and normal on the plane of fracture from the initiation point of stress.
3. The two components working at 45-16° and 45+16° that are at 29 and 61 degree direction gives the orientation of progress of stress components on the globe.
4. Magnitude of the stress components can be estimated with equation (a) and (b) presented in the introduction section and by the statements relation.BullSeismol.Soc.America 73, 471-fig.

Acknowledgement
We acknowledge and bid gratitude to Dr PRR Reddy Director (Rtd) NGRI, Hyderabad for giving me valuable guidance and review works on the abstract and my concerned paper on different levels. Thanks and Gratitude to Prof. DV Reddy Chief Editor IJEE Hyderabad for providing me data on events from NASA website and IPS Australian Government. Special thanks and gratitude to the NASA website for the Eclipse data for next 2000 years. Thanks and gratefulness’ to various concerned author for citing their fig and reference in the list of references. Highly gratitude and acknowledgement is bid to Mr P Hollis watts Research scholar, Kurten University, W. Australia for providing updated TEC and MMC data for confirmation of my list of prediction for the events for April and May 2012. Thanks and gratitude to Australian govt. weather forecast dept. for supporting with the data supply on TEC and OLR. Finally thanks to my colleague and my all nearest helping me at financing level.

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