Study on crustal activity in Tengchong volcano area

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Abstract. By constructing GNSS deformation rate, strain and stress mathematical relationship model; On this basis, the strain and stress data of the Tengchong volcanic area and surrounding areas were calculated through the deformation rate data; Based on the comprehensive analysis of the above data, it was found that: The underground magma sac in Tengchong volcanic area might be in the expansion period; From a macro point of view, the dynamic basis of the crustal deformation in the Tengchong volcanic area was mainly due to the fact that the material on the Qinghai-Tibet Plateau was squeezed by the South China Plate during the eastward flow of materials; And turning to the Yunnan-Burma active masses in the southwest direction, the crust of the Tengchong volcanic area showed a north-south extension and east-west compression.

1. Introduction
In recent years, the frequent occurrence of volcanic eruptions, it has caused serious property and personnel losses [1-9]. For example, the Mount Sinabung volcano (Mount Sinabung) suddenly erupted in August 2010 after 400 years of silence, and the intermittent eruption continues to this day [10-11]. It is worth noting that according to the "Xu Xiake's Travel Notes", the Tengchong volcano had a small-scale eruption in 1609 (411 years ago), which coincided with the eruption of Sinabung volcano at a high point in time. GNSS technology is currently one of the most commonly used methods for monitoring crustal deformation. Continuous measurement through regionally deployed GNSS networks can provide high-precision and high-resolution surface motion information [12]. A large amount of volcano horizontal deformation monitoring data has been obtained by applying GNSS method. Iceland has carried out GPS observations in the volcanic area in 1986; Sigmundsson et al. monitored the surface deformation caused by the eruption of the Hekla volcano [13]; from 1990 to 1994, Marshall et al. repeated the analysis of GPS observation data every year to obtain the surface expansion caused by the cracking of the Changgu volcanic wall [14]. GPS monitoring data provide great help in the research and determination of underground magma pressure change process. Owen et al. analyzed the repeated observation data of 70 GPS observation stations of Hawaii Volcano from 1990 to 1996, and obtained the horizontal velocity. The result showed that the displacement rate of several observation points around the Mauna Loa crater was very high from January 1999 to May 2002. It was small and the rate difference was also small. It was inferred that there is no obvious magma activity at this stage; however, from May to September 2002, the volcanic area experienced significant swelling. It was speculated that the magma source has experienced a strong pressure increase process [15-16]. GU et al. obtained the crustal movement trend in Hawaii through the data processing results of the continuous GPS observation station.
NA12 of the Nevada Geodetic Laboratory (http://geodesy.unr.edu); and analyzed the occurrence of Kilauea in Hawaii on May 5, 2018. Vue volcano erupted and 6.9 magnitude earthquake [17].

In this paper, the deformation rate data was used to obtain the strain and stress data of the studied area by constructing the mathematical relationship model of GNSS deformation rate, strain and stress. The discussion of activity is of great significance to the study of geodynamics and disaster reduction prediction in the region.

2. Structure background

The Tengchong volcanic area (24°45'N – 25°36'N, 98°20'E – 98°48'E) domain is a well-known Cenozoic volcanic activity area in China (the crust-mantle material exchange is relatively active)[18], located in the Yunnan-Burma active block at the junction of the Qinghai-Tibet active block and the South China active block, such as figure 1. The continuous collision of the Indian and Eurasian plates since 55 Ma has not only caused the compression structure in the southern Qinghai-Tibet Plateau, but also the extensional structure in Southeast Asia. Under such a geological structure, the Tengchong volcanic area has also been created. In a complex tectonic movement background, including volcanic activity, fault zone activity and eastward flow of material on the Qinghai-Tibet Plateau, GPS observation results [19] intuitively showed that the macroscopic horizontal movement background field of the Tengchong volcanic area was affected by the eastward flow of material from the Qinghai-Tibet Plateau. The impact is shown in Figure 2.
3. Model construction

3.1. Deformation-strain model construction

The main methods for calculating strain using GNSS velocity field data are Delaunay triangle method, interpolated uniform grid method and least squares collocation method. When the Delaunay triangle method calculates the strain, the data of the three GNSS observation stations are closely connected, and the accuracy of the calculation result is affected by the data of the three observation stations. When calculating the strain by the interpolation uniform grid method, due to the principle and algorithm of the uneven distribution of GNSS sites, a uniform average strain rate is calculated in the uneven area, which causes the analysis result to deviate from the actual situation. Therefore, this method is suitable for research areas with evenly distributed GNSS sites. The least squares configuration model is a generalized adjustment data processing method. Its processing results have the advantages of high accuracy, excellent stability, and less influence by the spatial distribution of GNSS observing stations. Taking into account the complex terrain of the Tengchong volcano area and the uneven distribution of GNSS sites (Figure 2), this paper uses the least squares configuration method to calculate the crustal strain field in this area.

3.1.1. Least squares configuration method model and parameter determination. Suppose there are m0 observed (or calculated) values of known points in the area to be interpolated, set to \( L = (g_1, g_2, \ldots, g_{m0})^T \). The median error of each point value \( g_i \) is \( m_0 g_1, i = 1, 2, \ldots, m0 \). \( t \) is the known point signal to be filtered; \( n \) is the observation error vector; \( s \) is the point signal to be estimated; \( n \) and \( t \) is centrally distributed. Then the basic equation of least squares configuration is:

\[
L = t + n
\]

Then

\[
\hat{t} = C_t (C_t + C_{nn})^{-1} L
\]

\[
\hat{s} = C_s (C_s + C_{ns})^{-1} L
\]

\( C_t \) is the prior auto-covariance matrix of the known point signal \( t \); \( C_{nn} \) is the auto-covariance matrix of the observation error vector; \( C_{ns} \) is the covariance between the signal of the point to be estimated and the signal of the measured point \( t \). The covariance of \( \hat{t}, \hat{s} \) is calculated as:

\[
C_{\hat{t}\hat{s}} = C_{ss} - C_{ts} (C_{tt} + C_{nt})^{-1} C_{nt}
\]
Denote the value of a point to be estimated with a coordinate of \((x, y)\) as \(g\). And use \(c(a, b)\) to represent variable \(a\) and the covariance between \(b\). So you can get:

\[
L = \sum_{i=1}^{m_0} g_i^2 + \sum_{j=1}^{m_0} g_j^2 + \sum_{i=1}^{m_0} g_i g_j \frac{1}{m_0} \sum_{j=1}^{m_0} g_j^2.
\]

In the above formulas, \(C_{aa}\) and \(C_{bb}\) are based on the same Gaussian empirical covariance function:

\[
f(d) = f(0) e^{-k^2d^2}.\]

Among them, \(d\) is the distance between two points; \(k\) is a parameter to be determined. Suppose \(C_{ab}\) is a diagonal matrix with equal diagonal elements; these diagonal element are recorded as \(f_{xx}(0) = \frac{1}{m_0} \sum_{j=1}^{m_0} g_j^2\) and \(f_{yy}(0) = \frac{1}{m_0} \sum_{j=1}^{m_0} g_j^2\); Then \(f(0) = f_{xx}(0) - f_{xy}(0)\).

Determining the parameters is the key to the realization of the least squares configuration, but in general, it is difficult to obtain a reliable covariance graph. This article determines the parameters according to the distribution of the measurement points in the specific area, that is, first determine the fitting amount in the entire area. The correlation distance \(S\) (that is, beyond this distance, the covariance value between points is close to zero), and the parameter

\[
k = \min_k \left\{ e^{-k^2S^2} : e^{-k^2S^2} \leq 10^{-3} \right\}
\]

Let \(d_{ij}, i, j = 1, 2, \cdots, m_0\) be the distance between any two points, and

\[
d_{\min} = \min_i \{ \min_j d_{ij} \}; \quad d_{\max} = \max_i \{ \min_j d_{ij} \}; \quad D_{\max} = \max_i \{ \max_j d_{ij} \}
\]

Respectively defined as minimum adjacent point distance, average adjacent point distance, maximum adjacent point distance and maximum point distance. Desirable:

\[
S \in (\max \{ 1.2d_{\max}, 0.2D_{\max} \}, \max \{ 1.5d_{\max}, 4d_{\max}, 0.25D_{\max} \})
\]

And

\[
S \leq 0.5D_{\max}
\]

3.1.2. Establish the spatial distribution model of strain field. We used the aforementioned least squares collocation method to obtain the horizontal apparent strain field distribution by establishing the empirical covariance function of the horizontal motion velocity value, and used the partial derivative relationship between displacement and strain. When the study area was large, the deviation angle between the latitude and longitude directions (representing positive WE and SN) of the station and the X and Y axis of the projection plane should be considered, so that the calculated strain parameters had exact meaning. Assuming that a monitoring network had \(m_0\) measuring points,

\[
L = (u_1, u_2, \cdots, u_{m_0}, v_1, v_2, \cdots, v_{m_0})^T
\]

was the positive E and positive N displacement observations (the latitude and longitude tangent directions of the site). The latitude and longitude coordinates were \((L_i, B_i)\), and the corresponding projection plane \(X, Y\) coordinate values \(x_i, y_i, i = 1, \cdots, m_0\). The angle between the tangent direction of the meridian of point \(i\) and the Y-axis (north) direction of the projection plane Cartesian coordinate system was \(\theta_i\), which was corrected to the coordinate values of the corresponding Cartesian coordinate system pointing to the positive WE and SN directions as \(x'_i, y'_i\). Assuming the x-direction and x-direction displacement, the covariance between the y-direction and y-direction displacement, the establishment parameters were \(f_{xx}(0), k\) respectively; \(f_{yy}(0)\) was the Gaussian empirical covariance function of \(k\), and the covariance of x-direction displacement and y-direction displacement is zero, so \(P = (p_1, \cdots, p_{m_0}, q_1, \cdots, q_{m_0})^T = (C_{aa} + C_{ab})^{-1}L\); Then the horizontal displacement of any point in the study area can be expressed as
Correction of the two displacement components in the E and N directions WE, SN (calculation point latitude, meridian tangent) direction deviation were:

\[
\begin{align*}
\frac{\partial u}{\partial x'} & = \sum_{i=1}^{m_0} \left\{ -2k^2 (x-x_i) f_{xx}(0)e^{-k^2d_i^2} p_i \cos \theta_i - 2k^2 (y-y_i) f_{xx}(0)e^{-k^2d_i^2} p_i \sin \theta_i \right\}, \\
\frac{\partial u}{\partial y'} & = \sum_{i=1}^{m_0} \left\{ 2k^2 (x-x_i) f_{xx}(0)e^{-k^2d_i^2} p_i \sin \theta_i - 2k^2 (y-y_i) f_{xx}(0)e^{-k^2d_i^2} p_i \cos \theta_i \right\}, \\
\frac{\partial v}{\partial x'} & = \sum_{i=1}^{m_0} \left\{ -2k^2 (x-x_i) f_{yy}(0)e^{-k^2d_i^2} q_i \cos \theta_i - 2k^2 (y-y_i) f_{yy}(0)e^{-k^2d_i^2} q_i \sin \theta_i \right\}, \\
\frac{\partial v}{\partial y'} & = \sum_{i=1}^{m_0} \left\{ 2k^2 (x-x_i) f_{yy}(0)e^{-k^2d_i^2} q_i \sin \theta_i - 2k^2 (y-y_i) f_{yy}(0)e^{-k^2d_i^2} q_i \cos \theta_i \right\}.
\end{align*}
\]

According to the definition of strain, the strain tensor at any point in the calculation area could be obtained from the above four equations.

3.1.3. Strain value calculation. \( \varepsilon_x = \frac{\partial u}{\partial x'}, \quad \varepsilon_y = \frac{\partial v}{\partial y'}, \quad \gamma_{xy} = \frac{\partial u}{\partial y'} + \frac{\partial v}{\partial x'}, \quad \omega = 0.5\left( \frac{\partial u}{\partial y'} - \frac{\partial v}{\partial x'} \right) \)

First shear strain \( \gamma_1 = \varepsilon_x - \varepsilon_y \), Second shear strain \( \gamma_2 = \gamma_{xy} \), Maximum shear strain \( \gamma_{\text{max}} = \sqrt{\gamma_1^2 + \gamma_2^2} \)

\[ \varepsilon_1 = 0.5\left( \frac{\partial u}{\partial x'} + \frac{\partial v}{\partial y'} \right) + 0.5\sqrt{\gamma_1^2 + \gamma_2^2}, \quad \varepsilon_2 = 0.5\left( \frac{\partial u}{\partial y'} + \frac{\partial v}{\partial x'} \right) - 0.5\sqrt{\gamma_1^2 + \gamma_2^2}, \]

Main strain:

The angle between \( \varepsilon_2 \) and \( y' \) axis was \( \phi = 0.5\arctan \left( \frac{-\gamma_{xy}}{\varepsilon_x - \varepsilon_y} \right) \); The angle between the maximum shear strain and the \( y' \)-axis was \( \phi + 45^\circ \); Surface expansion \( \Delta = \varepsilon_x + \varepsilon_y \). The calculation results were shown in Figure 3, 4, 5, 6, and 7.
Figure 3. First shear strain rate.

Figure 4. Second shear strain rate.

Figure 5. Area expansion rate.

Figure 6. Maximum shear strain rate.
3.2. Strain-stress model construction

3.2.1. Strain tensor. In the continuous medium, the relative position of any point and the reference point can be described by a vector field, that is, the displacement field is:

\[ u(r_0) = r - r_0 \]

In the formula, \( r \) is the current position; \( r_0 \) is the position of the reference point. The displacement \( u = (u_x, u_y, u_z) \) of a certain point \( r \) at \( r_0 \) small distance from the reference position \( r_0 \). Perform Taylor series expansion for each component of \( u \), and only take the first-order term, there is

\[
\begin{align*}
    u_x &= u_x(r_0) + \frac{\partial u_x}{\partial x} dx + \frac{\partial u_x}{\partial y} dy + \frac{\partial u_x}{\partial z} dz \\
    u_y &= u_y(r_0) + \frac{\partial u_y}{\partial x} dx + \frac{\partial u_y}{\partial y} dy + \frac{\partial u_y}{\partial z} dz \\
    u_z &= u_z(r_0) + \frac{\partial u_z}{\partial x} dx + \frac{\partial u_z}{\partial y} dy + \frac{\partial u_z}{\partial z} dz
\end{align*}
\]

The matrix form is:

\[
\begin{bmatrix}
    u_x \\
    u_y \\
    u_z
\end{bmatrix}
= u(r_0) +
\begin{bmatrix}
    \frac{\partial u_x}{\partial x} & \frac{\partial u_x}{\partial y} & \frac{\partial u_x}{\partial z} \\
    \frac{\partial u_y}{\partial x} & \frac{\partial u_y}{\partial y} & \frac{\partial u_y}{\partial z} \\
    \frac{\partial u_z}{\partial x} & \frac{\partial u_z}{\partial y} & \frac{\partial u_z}{\partial z}
\end{bmatrix}
\begin{bmatrix}
    dx \\
    dy \\
    dz
\end{bmatrix}
= u(r_0) + Jd
\]

Here \( d = r - r_0 \). Separate the rigid rotating part by dividing \( J \) into symmetric and anti-symmetric parts:
Here $e$ is symmetric ($e_{ij}=e_{ji}$), called the strain tensor, which can be expressed as:

$$
e = \begin{pmatrix}
\frac{\partial u_x}{\partial x} & \frac{1}{2} \left( \frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial x} \right) & \frac{1}{2} \left( \frac{\partial u_x}{\partial z} + \frac{\partial u_z}{\partial x} \right) \\
\frac{1}{2} \left( \frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial y} \right) & \frac{\partial u_y}{\partial y} & \frac{1}{2} \left( \frac{\partial u_y}{\partial z} + \frac{\partial u_z}{\partial y} \right) \\
\frac{1}{2} \left( \frac{\partial u_x}{\partial z} + \frac{\partial u_z}{\partial z} \right) & \frac{1}{2} \left( \frac{\partial u_z}{\partial y} + \frac{\partial u_y}{\partial z} \right) & \frac{\partial u_z}{\partial z}
\end{pmatrix}
$$

3.2.2. Linear stress-strain relationship.

In elastic media, stress and strain are connected through a stress-strain constitutive relationship. The most general linear relationship between stress tensor and strain tensor can be written as:

$$\sigma_{ij} = c_{ijkl} e_{kl} = \sum_{k=x,y,z} \sum_{l=x,y,z} c_{ijkl} e_{kl}$$

In the formula, $c_{ijkl}$ is the elasticity Tensor. The elastic constant is a fourth-order tensor with 81 ($3^4$) elements. However, due to the symmetry of the stress tensor and strain tensor, they each have only 6 components, at this time $c_{ijkl} = c_{jikl} = c_{iklj} = c_{ijlk}$. Therefore, the expression between the stress component and the strain component can be expressed as:

$$\sigma_{xx} = c_{xxxx} e_{xx} + c_{xyxy} e_{yy} + c_{xxyz} e_{z} + c_{xyxy} e_{xy} + c_{xyzx} e_{yx} + c_{xxxx} e_{zz}$$

$$\sigma_{xy} = c_{xyyx} e_{yy} + c_{xyzy} e_{zy} + c_{xyzy} e_{xy} + c_{xyxy} e_{yy} + c_{yxzx} e_{zx} + c_{xyxy} e_{yx}$$

$$\sigma_{xz} = c_{xxzx} e_{zx} + c_{xxyz} e_{yz} + c_{xxzy} e_{zx} + c_{xxzx} e_{xx} + c_{xxzy} e_{yz} + c_{xxzx} e_{zz}$$

$$\sigma_{yy} = c_{yyyy} e_{yy} + c_{yyzy} e_{zy} + c_{yyzy} e_{yy} + c_{xxzx} e_{xx} + c_{yyzy} e_{yx} + c_{yyzy} e_{yx}$$

$$\sigma_{yz} = c_{yyzy} e_{zy} + c_{yyzy} e_{zy} + c_{yyzy} e_{zy} + c_{yyzy} e_{zy} + c_{yyzy} e_{zy} + c_{yyzy} e_{zy}$$

$$\sigma_{zz} = c_{zzzz} e_{zz} + c_{zzzy} e_{zy} + c_{zzzy} e_{zz} + c_{zzzy} e_{zy} + c_{zzzy} e_{zy} + c_{zzzy} e_{zz}$$

Above equation has only 36 elastic constants. It can be proved that for a conservative system (that is, no energy loss):

$$c_{xyyx} = c_{yyxy}, c_{xxzx} = c_{zzxx}, c_{zyzy} = c_{zyzy}, c_{xyzy} = c_{zxzy}, c_{xzyy} = c_{xzyx}, e_{xx} = e_{xx}, c_{yyyy} = c_{yyyy},$$

$$c_{zyzy} = c_{zyzy}, c_{xxzx} = c_{zzxx}, c_{zyzy} = c_{zyzy}, c_{xyzy} = c_{zxzy}, c_{xzyy} = c_{xzyx}, c_{yzyz} = c_{yzyz},$$

Therefore, for extremely anisotropic media (If the properties of a solid change with direction, the medium is said to be anisotropic. In contrast, isotropic solids have the same properties in all directions.), there are 21 independent elastic parameters, and only 21 of these elements are independent. These 21 elements are necessary to determine the most general form of stress-strain relationship for elastic solids. In this paper, an isotropy
assumption is made, and the independent parameters are reduced to two: \( \lambda \) and \( \mu \), which are the Lame constants of the crust.

\[
c_{ijkl} = \lambda \delta_i \delta_j + \mu (\delta_i \delta_k + \delta_j \delta_k)
\]

among them

\[
\delta_i = \begin{cases} 1 & i = j \\ 0 & i \neq j \end{cases}
\]

Therefore

\[
c_{xxxx} = c_{yyyy} = c_{zzzz} = \lambda + 2\mu, \quad c_{xxyy} = c_{xxzz} = c_{yyyy} = \lambda, \quad c_{xyxx} = c_{yxyy} = \mu,
\]

\[
c_{xxyy} = c_{xxzz} = c_{yyzz} = c_{xyxx} = c_{xxyy} = c_{zzzz} = 0, \quad c_{yxyy} = c_{xxyy}
\]

\[
c_{zyzz} = 0
\]

For an isotropic solid, the stress-strain equation is:

\[
\sigma_{ij} = \left[ (\lambda + 2\mu) \delta_i \delta_j + \mu (\delta_i \delta_k + \delta_j \delta_k) \right] e_{ij} = \lambda \delta_i e_{kk} + 2\mu e_{ij}
\]

Use \( e_{ij} = e_{ji} \) to combine items that contain \( \mu \), as 2\( \mu e_{ij} \cdot e_{kk} = tr[e] \) is the sum of the diagonal elements of \( e \). Using formula \( \sigma_{ij} \), the stress tensor can be written directly according to the strain tensor:

\[
\sigma = \begin{bmatrix}
\lambda tr[e] + 2\mu e_{xx} & 2\mu e_{xy} & 2\mu e_{xz} \\
2\mu e_{yx} & \lambda tr[e] + 2\mu e_{yy} & 2\mu e_{yz} \\
2\mu e_{zx} & 2\mu e_{zy} & \lambda tr[e] + 2\mu e_{zz}
\end{bmatrix}
\]

### 3.2.3. Stress calculation.

According to the above Strain tensor \( e \), based on the GNSS least squares configuration model to calculate the surface expansion rate, the first shear strain rate, the second shear strain rate and the velocity field formula, where \( \frac{\partial u_x}{\partial x} = \frac{\partial u_x}{\partial x} = \frac{\partial u}{\partial y}, \quad \frac{\partial u}{\partial y} = \frac{\partial u}{\partial y}, \quad \frac{\partial u}{\partial x} = \frac{\partial u}{\partial x} \), establish the mathematical relationship between the calculated strain and the strain tensor:

\[
e = \begin{bmatrix}
\frac{\partial u_x}{\partial x} & \frac{1}{2} \left( \frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial x} \right) \\
\frac{1}{2} \left( \frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial y} \right) & \frac{\partial u_y}{\partial y}
\end{bmatrix} = \begin{bmatrix}
\varepsilon_x & \frac{1}{2} (\varepsilon_x + \varepsilon_y) \\
\frac{1}{2} \gamma_{xy} & \varepsilon_y
\end{bmatrix}
\]

According to the above linear stress-strain relationship, the stress tensor is calculated from the strain tensor, and the vector direction of the velocity (including the northward velocity and the eastward velocity) calculated based on the GNSS least squares configuration model is used as each deformation point in the surface plane Normal vector within; Finally, according to the expression of the stress tensor, the shear stress and normal stress of the stress tensor on the surface plane whose normal direction is the velocity vector direction are shown in Figure 8 and Figure 9, and the calculation process is shown in Figure 10.
4. Result analysis

The volcanic area was located in the median area of unit area expansion at about \(0.7 \times 10^{-8}/yr \sim 0.9 \times 10^{-8}/yr\), and its eastward direction was expressed as a low-value area of expansion, and its value was about \(0.3 \times 10^{-8}/yr \sim 0.6 \times 10^{-8}/yr\). The south direction was expressed as a median area closer to the volcanic area, and the northeast and southwest directions were expressed as The high value area of expansion was about \(0.9 \times 10^{-8}/yr \sim 1.2 \times 10^{-8}/yr\), and the overall performance was expansion (Figure 5). It can be seen from Figure 6 that the volcanic concentrated distribution area was located in the high value area of tectonic activity, the maximum value area was located in the southeast of the volcanic area, the maximum shear strain value of the volcanic area was about \(4.9 \times 10^{-8}/yr \sim 5.1 \times 10^{-8}/yr\), and the tectonic activity was stronger than that of the surrounding areas; The spatial distribution characteristics of the above expansion rate and maximum shear strain rate indicate that the underground magma sac in the Tengchong volcanic area might be in an active expansion.
stage. It could be seen from the principal strain that the Tengchong volcanic area was stretched in the north-south direction, and compressed in the east-west direction (Figure 7). The spatial distribution of the principal strain implies: As the material flow on the Qinghai-Tibet Plateau was hindered by the active masses in South China, the material flow turned clockwise toward the southwest and the Yunnan-Burma active masses were compressed, which made the east-west compression appear, and the east-west compression again made the material move toward Escape occurred in the north-south direction, which made the north-south direction to be stretched. The numerical characteristics of the overall stretch greater than the compression implied that the Myanmar-Burma active block had a greater resistance to the clockwise flow of material from the Qinghai-Tibet Plateau to the southwest than in the Tengchong volcanic area. The ability of material to escape to the north and south.

Based on the spatial distribution characteristics of the shear stress (Figure 8), it was found that the shear stress in the volcanic area was located west of the intersection of the low-value area and the high-value area, and its value range was about 3000Pa~11000Pa; The high value area was located in the northwest and southeast corners of the study area, and its numerical range was about 15000Pa~40000Pa; The low-value areas were located in the southwest and northeast corners of the study area, and their numerical range is about -17000Pa~5000Pa; The above characteristics indicate: Due to the clockwise flow of material from the Qinghai-Tibet active block towards the Myanmar-Burma active block, the material has been accumulating in the northwest of the study area. The accumulated material has been further escaping and driving the counter clockwise deflection of the crust in the northeast and southwest corners of the study area to produce negative shear stresses. The absolute value of the normal stress in the high-value area and the normal stress in the low-value area has further proved that the counter clockwise deflection of the crust in the northeast and southwest corners was caused by the material flowing from the Qinghai-Tibet Plateau to the southwest. The positive shear stress in the southeast corner of the study area was further driven by the counter clock wise deflection of the crust in the northeast and southwest corners. Based on the numerical spatial distribution characteristics of normal stress (Figure 9), it was found that the normal stress value changes roughly linearly from northeast to southwest. The extremely low value area of the entire area appeared in the east of the large area where the Tengchong Volcanic Area was located, and the extremely high value area appeared in the southwest corner of the large area where Tengchong Volcanic Area was located, the positive stress value of Tengchong Volcanic Area was about -45000Pa~15000Pa at the junction area where the direction of the positive stress changed to the negative area of the positive stress; the positive stress value of the entire large area was about -60000Pa~90000Pa.

5. Conclusion
The least squares configuration model was processed to obtain GNSS deformation rate data, and the inversion deformation rate, surface expansion rate, first shear strain rate and second shear strain rate were obtained respectively. The crustal surface strain tensor was calculated from the above data. The linear stress-strain relationship model obtained the shear stress and the normal stress. Based on the data obtained above, the analysis found that the underground magma sac of Tengchong volcanic area may be in the expansion period; The crust of the Tengchong volcanic area showed a north-south extension and east-west compression, and the compression capacity is greater than extension; The dynamic basis of the crustal deformation in the Tengchong volcanic area was mainly caused by the flow of material from the Qinghai-Tibet Plateau to the southwestern Yunnan-Burma active block during the eastward flow of material from the South China plate.

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