Sediment subduction: a probable key for seismicity and tectonics at active plate boundaries

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SUMMARY
A model involving extensive occurrence of sediment subduction and viscous interaction of lithospheric plates at convergent zones is applied to derive simple relations between extremal values of seismic and global tectonic parameters. The strength of mechanical coupling at the interface zone is defined as the maximum shear stress at the base of the over-thrusting plate. A test of these relations with the data set on great thrust earthquakes supports this model. Moreover, it reveals independently of previous studies the main contrasting modes of subduction stress regimes (continental-island arc-types, and Chilean-Mariana-types). An analysis of asperity categories in the framework of this model leads to the conclusion that the asperity type, and probably the fault area of great earthquakes, depends on the strength of coupling, which in its turn is governed by global tectonics and the amount of subducted sediments. The approach also yields a physically reasonable dependence of the seismic slip on the plate parameters, which is in agreement with the data now available.

Key words: Asperity, earthquakes, plate coupling, sediment subduction, seismic slip

1 INTRODUCTION
The strongest argument for sediment subduction originates from the relatively small observed volumes of accreted wedge sediments in comparison with the volumes calculated under the assumption that all deposits transported with the oceanic lithosphere to the trench have been accreted (Scholl et al. 1977). However, an accurate evaluation of the sediment subduction/accretion balance is not yet possible on the global scale because of the lack of reliable data (Hilde 1983).

Which basic type of tectonic process involving sediments (subduction, accretion, erosion, subduction kneading; Scholl et al. 1980) is dominant in subduction zones? This question arises when the relatively low values of the viscosity of ocean deposits are recognized. This has been done intuitively in some recent studies on convergent plate boundaries, and led to the logical conclusion that sediment subduction takes place where coupling-stress at the plate interface is low (Uyeda 1982, 1983, 1984). In zones of high coupling-stress soft sediments would be scraped off or squeezed out from the interplate contact, warped and accreted to the fore-arc wedges (Ruff & Kanamori 1980).

Nevertheless there is an increasing amount of evidence that sediment subduction is a more extensive process even in very high coupling-stress zones (Hilde 1983; Karig & Kay 1981; Brown et al. 1982). This contradicts the common notion of low viscosity of oceanic deposits. Two approaches exist to resolve this problem (Uyeda 1984). The first is to construct a world-wide mechanical model of trapping of soft sediments, for example, by means of bending-induced graben structures of the subducting plate (Lister 1971; Hilde 1983). The other is to investigate plausible models of diagenesis and catagenesis of ocean deposits in plate interfaces which result in viscosity increases up to a reasonably high value (Sorokhtin & Lobkovsky 1976). Both mechanisms are realized together in nature but in the case of relatively high viscosity the amount of ocean deposits involved in subduction would be a very important parameter for the tectonics and seismicity of active plate boundaries. Fig. 1(a) illustrates this schematically. The maximum value of shear stress on the base of the overriding plate is defined here as a measure of the strength of mechanical coupling.

According to the elastic rebound theory (Reid 1911; Kasahara 1981) subduction is accompanied by a cyclic process of long-term interseismic deformation of the overthrusting lithospheric block. This is followed by a shot-like release of the accumulated elastic strain energy in an earthquake. Seismicity observations indicate that rupture planes of large and great thrust earthquakes correspond to contact zones of the plates. The physics and structure of the subduction interface are poorly known, and a simple dry friction (DF) model or even locking between plates is usually presumed for interseismic periods (Sorokhtin & Lobkovsky 1976; Lobkovsky 1986). The main difficulty in this case is the mechanical meaning of the strength or the degree of coupling. If the plates are locked, differences in coupling should display themselves only during seismic events as variations in seismic/aseismic slip (Kanamori 1986; Peterson & Seno 1984), expansion patterns of aftershock
areas (Mogi 1968) or asperity types (Ruff & Kanamori 1980). All these phenomena as well as magnitudes of great earthquakes \( M_w \) have noticeable correlations with subduction plate parameters, convergence rate \( V \) and age of the lithosphere \( A \), but there is no clear physical understanding of these correlations within the framework of DF model.

A regression analysis of the available data gave an empirical relation (Ruff & Kanamori 1980; Kanamori 1986):

\[
M_w = 0.009353 A + 0.143 V + 8.1
\]

where \( A \) is in million years and \( V \) is in cm-yr\(^{-1}\). The equation (1) is very useful to estimate maximum possible magnitude of thrust events in a particular subduction zone (Kanamori & Astiz 1985). However, it is senseless to interpret this or similar (Jarrard 1986) statistical relations in terms of the strength of plate coupling if the latter term is not identified explicitly enough. For example, an asperity model (Byerlee 1970) extended to earthquake faults seemed to be very close to resolving the problem (Ruff & Kanamori 1980). Careful analysis of seismic body-waves radiated from large thrust earthquakes indicate that some regions of the fault planes, called asperities, had greater strength than others (Lay & Kanamori 1980; Ruff & Kanamori 1983). The dimensions of these regions and their relative density on the fault plane are correlated with the size of rupture area or with magnitude \( M_w \) (Lay et al. 1982). Nevertheless, even the asperity model cannot clarify the internal relation between seismic and plate parameters because the physical meaning of asperities is not specified.

Although asperities are very important phenomena themselves, the asperity model gives no plausible answer as to why a relative increase in the amount of trench sediments in some subduction zones (Alaska, South Chile) can 'facilitate strong coupling' (Ruff & Kanamori 1983) but in other trenches with excess of sediments (Caribbean, Java) the strength of coupling is too low to produce great earthquakes.

This problem can be eliminated when the viscous interface model (V-model) is considered (Fig. 1a). A similar model was used recently (Lobkovsky 1986) to describe formally the cycle of great earthquakes in subduction zones in terms of autorelaxation oscillations of the overthrusting lithospheric block (Fig. 1b). The main intention of the present study is to test the V-model in a general sense by a rough comparison of, on the one hand, extremal values of the displacement \( U_m \) and elastic strain energy \( W_m \) of the overthrusting block estimated from the V-model for the period between great earthquakes, and on the other hand, the data on average coseismic displacement \( U \) and energy \( \Delta W \) or the magnitudes \( M_w \) released by great earthquakes (Ruff & Kanamori 1980; Lay et al. 1982).

2 THE MODEL

Let us assume that elastic deformation of the overthrusting plate is compressional (Pflaffer 1972) and concentrated mostly in the lower part of its leading edge corresponding to the megathrust interface zone (Hayakawa 1984). The constitutive relation for the interface (altered sediments) is defined as viscous (Newtonian). A simple model consisting of a spring and block can be used in this case. All notations are shown on Fig. 1b. The block is of unit width and \( k' \) is the rigidity of the spring which simulates an elastic reaction of the rest of the medium.

An equation for displacement \( U(x, t) \) similar to the equation of heat conduction comes from the balance of forces applied to an infinitesimal part of the block \( dx \) at point \( x \):

\[
\frac{\partial U}{\partial t} = k(\frac{\partial^2 U}{\partial x^2}) + V \quad \kappa = Eh/\eta
\]

where \( t \) is time, \( V \) is convergence rate, \( \eta \) is viscosity of the interface layer, and \( E \) is Young's modulus of the lithosphere. With boundary conditions corresponding to a free right-hand end of the block \( (x = 0) \) and with an elastic reaction of the spring at the left end \( (x = L) \):

\[
\begin{align*}
\frac{\partial U}{\partial x} &= 0 \quad x = 0 \\
\frac{\partial U}{\partial x} + kU &= 0 \quad x = L, \quad k = k' E
\end{align*}
\]
Equation (2) has a solution (Carslaw & Jager 1959):

\[ U(x, t) = \frac{V}{2\kappa k} \times \frac{2L + kl^2 - kx^2 - 4k^2}{\exp(-\alpha_n^2 t) \cos(\alpha_n x) \alpha_n^2 \left[ \frac{L(\alpha_n^2 + k^2) + k}{L(\alpha_n^2 + k^2) + k} \cos(\alpha_n L) \right]} \]

where \( \alpha_n \) (n = 1, 2, 3, . . .) are the positive roots of \( \alpha \tan(\alpha L) = k \).

Although (4) is a little complicated, only extremal values of \( U \) and elastic strain energy \( W \) will be of interest later on when comparing them against observed data. The maximum displacement is at the free end of the block (x = 0) with \( t \to \infty \):

\[ U_w = L'V/2\kappa + LV/k \kappa , \]

where the first term corresponds to the maximum displacement caused by the deformation of the block and the second to the displacement of the block as a whole, which is limited only by elastic compression of the spring.

The total maximum elastic strain energy accumulated by the system (Fig. 1b) is:

\[ W_w = \int_0^L HE \left( \frac{\partial U}{\partial x} \right)^2 \, dx + \int_0^L k x dx = \frac{HELV^2}{3k^2} + \frac{L'V^2}{2k\kappa^2} . \]

Using reasonable average values of the parameters (\( L = 100 \text{ km}, H = 25 \text{ km}, \) and a length along the trench, \( l \), where \( l = 200 \text{ km} \)) Lobkovsky (1986) showed that the elastic strain energy of the block only is equivalent to the maximum earthquake magnitude \( M_w = 8 \). Of course, only some amount (\( \Delta W \)) of the total energy (\( W_m \)) is released seismically in the greatest possible earthquake for each subduction zone. The rest can be released in aseismic slip accompanying and following the main event. The maximum elastic strain energy of the system \( W_m \) is probably less than \( W_w \) because of inelastic dissipation of some of the strain energy during the interseismic period as a result of regional tectonic processes.

The distribution of strain (\( dw/dx \)) along the x-axis of the fault plane is unknown in the general case. Therefore \( \Delta W \) may be expressed in the linear approximation as:

\[ \Delta W = W_{m0}lw/L , \]

where \( w \) is the width, \( l \) is the length (along the trench) of the earthquake fault zone, and \( L \) is the length of the contact zone between the two plates.

Assuming now that older oceanic lithosphere subducts a relatively larger amount of sediments or that the thickness of the interface layer depends on the age (A) of subducting lithosphere, as

\[ h = avA , \]

where \( a \) is a constant, and \( v \) is an average pelagic sedimentation rate, then (6) and (7) can be transformed to:

\[ \Delta W = C \frac{V^2}{A^2} lw \quad C = \left( \frac{EHL^3}{3} + \frac{L}{2k} \right) \left( \eta \left( \frac{\eta}{EHav} \right)^{1/3} \right) \].

Finally, equation (9) can be used in combination with the dependence of energy versus fault-zone area (Kanamori 1977; Kasahara 1981):

\[ \Delta W \propto (lw)^{3/2} , \]

and the Gutenberg-Richter equation

\[ \log \Delta W = 1.5M_w + 11.8 , \]

to obtain an explicit relation:

\[ M_w = 4 \log (V/A) + 2 \log C + \text{constant} . \]  

In terms of the V-model the value of \( V/A \) determines the strength of coupling by definition because the maximum shear stress at the base of the overthrusting plate is:

\[ \tau_m = C_2 V/A \quad C_2 = \eta/av . \]

The expression (10) is a direct relation between seismicity (represented as \( M_w \)) and degree of plate coupling, which can be easily tested using the available data set.

3 THE DATA

Table 1 contains the data on very large and great thrust earthquakes in subduction zones, and corresponding plate parameters. It is compiled from the two main data sets published by Ruff & Kanamori (1980) and Lay et al. (1982). New observations on the 1983 Akita-Oki thrust earthquake off the western coast of Japan (Kanamori & Astiz 1985) are also included since this very probably represents the strongest event in the young subduction zone at the Japan sea.

Not every subduction zone in Table 1 has an estimation of the seismic moment (\( M_s \)) and moment magnitude (\( M_a \)) for its largest earthquake. In such cases (\( N > 15 \) in Table 1) surface-wave magnitude (\( M_w \)) is used instead.

Plate parameters specified for each subduction zone are selected mostly from the study of Shiono & Sugi (1985). Values of convergence rate (\( V \)) and age of the lithosphere (\( A \)) correspond approximately to the part of each subduction zone where the hypocentre of the largest earthquake has been recorded. All references on the original sources of the data can be found in the papers mentioned above.

It is important to note that the uncertainties in the parameters are rather large (at least 10-15 per cent for \( V, A, \) and 50 per cent or more for \( U \)). Convergence rates for the New Hebrides trench and the Nankai trough drastically depend on the plate-motion model used to calculate these parameters (Jarrard 1986). Earthquakes of the largest observed magnitude probably do not represent the maximum possible or 'characteristic' (Lomnitz-Adler 1985) earthquake at some of the trenches. This means that magnitudes of great earthquakes (for example, at the Java and Sumatra subduction zones) may be underestimated because of the lack of reliable historical records (Lay et al. 1982).

4 TEST OF THE V-MODEL

The number and quality of the data now available (Table 1) satisfy the test of the V-model only in a general sense.
Table 1. Seismicity and subduction parameters. $M_s$, surface wave magnitude; $M_w$, moment magnitude; $M_o$, seismic moment; $l$, length of a rupture zone; $w$, width of a rupture zone; $U$, average displacement; $V$, convergence rate; $A$, age of the lithosphere at the trench.

<table>
<thead>
<tr>
<th>No.</th>
<th>Region</th>
<th>Date</th>
<th>$M_s$</th>
<th>$M_w$</th>
<th>$M_o$ ($10^{23}$ dyn cm)</th>
<th>$l$ (km)</th>
<th>$w$ (km)</th>
<th>$U$ (m)</th>
<th>$V$ (cm/yr$^{-1}$)</th>
<th>$A$ (Ma)</th>
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<td>40-60</td>
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<td>80</td>
<td>3.1</td>
<td>200-300</td>
<td>50</td>
</tr>
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Nevertheless, the result of this test would not be substantially different if some of the data were revised. Maximum values of the magnitudes are plotted as a function of the logarithm of $V/A$ on Fig. 2(a). The most striking feature of this plot is that the data points are split into two distinct groups: island arc-type and continental arc-type (I and C on Fig. 2(a); see Table 1 for references) in accordance with widely accepted classification (Uyeda & Kanamori 1979) of subduction zones. But only three points are exceptional: Alaska (C-type, no. 10 in Fig. 2 and Table 1), Nankai trough (I-type, no. 2), and Solomon Islands (I-type, no. 1). The reason for these 'outlandish' points is not yet clear. Practically all points with $M_s \leq 8$ can be easily recognized on Fig. 2(a) as a group of so-called Mariana-type (weak coupling) subduction zones, and with $M_s > 8$ as a Chilean-type group (strong coupling; Uyeda & Kanamori 1979).

It is quite difficult at this stage to reveal the physical meaning of the division of the data set into I- and C-type groups. Some ideas could come from a rough analysis of the constant C in (9). The most probable parameters which may account for this phenomenon are $L$ and $k$ because others

Figure 2. A comparison of seismic (observed) and interseismic (modelled) characteristics of subduction zones, (a) A plot of magnitudes $M_o$ of great thrust earthquakes versus logarithm of the ratio $V/A$. Numbers near points are given as references for subduction zones as in Table 1. I is island arc-type (solid circles) and C is continental arc-type (open circles) of subduction zones (Uyeda & Kanamori 1979). Solid lines are the best-fit linear approximations with gradients of 3.2 for I-type and 2.9 for C-type groups. Dashed lines drawn through the mean points of each group have gradient 4, as predicted by the perfectly elastic model. Points for which asperity type is reported (Lay et al. 1982) are marked with special symbols. Each symbol and corresponding asperity-type illustration is given next to the magnitude scale at the right side of the plot. The rectangular size of the asperity illustrations characterizes the fault-zone area and the hatched
areas of the rectangles indicate the zone of strong coupling (asperities). Thin horizontal lines roughly subdivide the plot by bands of similar asperity types. \( \log (V/A) \) is calculated with \( V/A \) in \( 10^{-6} \text{ cm yr}^{-2} \). (b) Average coseismic displacements \( U \) as a function of the ratio \( V/A \). Vertical solid and dashed bars and boxes represent uncertainties in \( U \) and \( V/A \) estimations. \( U_r \) are negative 'residual' displacements interpreted as plastic (tectonic) deformations. The point no. 15 (South Chile, 1960) is probably an 'outlier'.

Legend for Figure 2 (Continued).
\( (E, H, a, v, \eta) \) seem to be of the same value for both types of subduction zone.

Each set of points in Fig. 2(a) was approximated by a straight line with gradients, determined by regression analysis of 3.2 for I-type and 2.9 for C-type. In contrast, the model (equation 10) predicts a gradient of 4. The gradient for the I-type set would fit the value 4 if the two most-scattered points, Caribbean (no. 25 in Fig. 2a) and Marianas (no. 18) were ignored.

The fact that the observed values of the gradients are less than those predicted by the model means that the model itself is too simple to evaluate the real elastic strain energy accumulation \( (W') \). The difference in gradients may be explained by an inelastic (plastic) dissipation of some strain energy. In that case continental arc-type subduction zones should expend relatively more strain energy on tectonic processes than island arc-type zones (see Fig. 2a). This conclusion is supported by the results of previous studies in which the recent vertical movement of shorelines was analysed for different subduction zones (Yonekura 1983).

An independent test for tectonic dissipation (or existence of a seismically non-recoverable part of the total displacement of the overthrusting plate) is provided by a direct comparison of the maximum interseismic displacement \( (U_m) \) and average coseismic displacement \( (U) \) estimated for great earthquakes in different subduction zones (Table 1). The comparison implies that all the elastic strain energy that can be accumulated by the system (Fig. 1b) would be released either seismically or aseismically in a particular subduction zone and result in an average slip \( (U) \) on the megathrust during the greatest earthquake. In this case \( U = U_m \), and from (5) and (8) \( U_m \) can be expressed as:

\[
U_m = C_1 \frac{V}{A} \quad \text{with} \quad C_1 = \left( \frac{1}{2} + \frac{L}{k} \right) \frac{\eta}{EHa_v} . \quad (12)
\]

Equation (12) indicates, again, the explicit dependence of the total displacement on plate coupling (11). In this sense an empirical relation \( U \) proportional to \( V/A \) (among others) should reveal the same features of subduction zones as the relation \( M_w \) proportional to \( V/A \). This can be seen in Fig. 2(b) where the data from Table 1 are presented in the form of a graph of \( U \) against \( V/A \). All points are split again into I- and C-groups but the difference in gradients of the regression lines now reflects variation of the model parameters \( L \) and \( k \) (as discussed above).

The intersections of the regression lines with the \( U \)-axis give negative values of coseismic displacement or 'residual' displacements that can be interpreted as some seismically non-recoverable amount of the total modelled interseismic displacement \( U_{in} \). Probably these residuals, 

\[
U_e = U_{in} - U ,
\]

are a measure of the present-day permanent deformation of the overthrusting lithospheric block. Long-term geodetic measurements in the region of the Great Nankaido earthquake of 1946 directly indicate that only a half of the interseismic deformation was released coseismically during this event (Thatcher 1984). This is approximately the same value as can be estimated from Fig. 2(b) (compare \( U_e \) and \( U \) for the bar no. 2 in Fig. 2b). Thus different values of \( U_e \) for island arc-type and continental arc-type subduction zones confirm the meaning of the gradients obtained from the plot of \( M_w \) against \( V/A \).

The value of the average coseismic displacement, \( U = 24 \text{ m} \), for the great Chilean earthquake of 1960 seems to be overestimated and inconsistent with other data (see Fig. 2b, the point no. 15) in terms of the present model. This may reflect the large uncertainty in the fault-zone area determination, particularly in the value of \( w \), estimated as 200 km (Kanamori & Cipar 1974).

5 ASPERITIES

After the main relation between magnitudes of great earthquakes and plate parameters was verified, the next problem to be considered was the importance of asperities. In order to do this every point on Fig. 2(a) is marked (if possible) with a special symbol corresponding to an asperity-group classification (Lay et al. 1982). An additional group (.) in Fig. 2(a) was also distinguished. In spite of the same asperity pattern as the group (.), earthquakes of the group (.) have relatively smaller fault-zone areas.

Even a brief examination of the asperity type distribution superimposed on the plot of \( M_w \) against \( V/A \) reveals a gradual change of the asperity type with magnitude. This change is, in most cases, equivalent for both I- and C-type subduction zones. Asperity estimations are not quantitative enough to make a detailed analysis at this stage; nevertheless it can be seen from Fig. 2(a) that the change from one asperity type to the next along the \( M_w \)-axis roughly corresponds to a magnitude increase by 0.5 unit which is equivalent to a threefold increase of the fault-zone area.

It is important to emphasize that the \( V \)-model, with its definition of the strength of coupling, does not require any additional assumptions to describe in general, within an accuracy of the data set now available, the seismicity and probable tectonics of active plate boundaries. Therefore, asperities are of secondary importance, in comparison with the tectonic parameters already discussed, in modelling the subduction process at plate boundaries. Asperities indicate only the final state in the process of rearrangement of the stress field in the plate interface zone just before each great earthquake.

If most of the stress in the contact zone is concentrated on certain spots (asperities), and the average strength of these asperities cannot be higher than a constant value \( \tau_0 \), then from (11)

\[
\tau_0 S_e / S = C_1 V / A = \tau_n . \quad (13)
\]

The asperity ratio \( S_e / S \), where \( S_e \) is the area of strong coupling on the fault, should increase as the overall strength of mechanical coupling rises in the global sense. Note that the left side of (13) is very similar to the strength of coupling defined by an asperity model (Kanamori 1986). Probably the rupture area dimensions \( (l, w) \) of the 'characteristic' earthquake are a consequence of the distribution of asperities and their sizes, which depend in turn on the strength of the plate coupling and the \( V/A \).

6 SEISMIC SLIP

Peterson & Seno (1984) argued that the amount of interplate seismicity quantified as seismic-moment release...
Figure 3. The dependence of seismic slip, \( \gamma = V_s/V_{\text{rel}} \), on the ratio of subduction parameters \( A/V \). All the estimates of \( \gamma, A \) and \( V \) are from Peterson & Seno (1984). Open circles are C-type subduction zones and the solid circles are zones of the I-type. Dashed lines show the shifts of points for Nankai trough (open circle) and New Hebrides subduction zone (solid circle) if the estimates of \( V \) and \( A \) are selected from Table 1 instead. The values \( \gamma = 1 \) is assumed for the South Chile zone because \( \gamma = 1.57 \) obtained by Peterson & Seno (1984) is physically unreal.

rates (\( \dot{M}_s \)) and seismic slip rates (\( V_s \)) is more representative than the magnitudes (\( M_s \)) of the largest events. They observed an approximately linear decrease of \( \dot{M}_s \) and \( \gamma = V_s/V_{\text{rel}} \) (\( V_{\text{rel}} \) is the relative plate velocity averaged over the arc) with increasing age, but only for the subduction zones belonging to a single plate. A lack of expected increase in \( \dot{M}_s \) with the convergence rate was surprising. A low general correlation between \( \dot{M}_s, \gamma, V \), and \( A \) seemed to contradict the results of previous studies (Ruff & Kanamori 1980; Lay et al. 1982). The estimates of \( \dot{M}_s \) and \( V_s \) (or \( \gamma \)) obtained by Peterson & Seno (1984) are probably the best available (Kanamori 1986). Therefore, it is very important to understand the reason for the contradiction. The V-model applied here gives a simple approximate dependence of the seismic slip (relative seismic-slip velocity, \( \gamma \)) on the subduction parameters. Since it can be assumed that the velocity changes linearly within the viscous sedimentary layer (see Fig. 1a,b), then

\[
V_s = V - bA,
\]

where \( b \) is a constant.

The proportion that is seismic, \( \gamma \), of the total slip, is approximately \( V_s/V \) because \( V_{\text{rel}} \approx V \), and

\[
\gamma \approx 1 - b(A/V).
\]

The relation (15) is easy to test with the estimates presented by Peterson & Seno (1984). Fig. 3 shows that (15) is in good general agreement with the data. All the subduction zones are split again into I- and C-type groups. It is rather difficult to envisage any mechanism other than the permanent deformation of the overriding lithosphere (as a result of an inelastic dissipation of strain energy) that would produce this splitting.

Unfortunately, there are considerable errors in the data because of uncertainties in recurrence time and seismic-moment estimates used to calculate \( V_s \). Large errors can arise in the estimates of convergence rates, particularly for the New Hebrides and Nankai trough zones. All these factors make it impossible to interpret Fig. 3 quantitatively. Nevertheless, the reason for the failure to obtain a straightforward correlation between \( \gamma, V \) and \( A \) is clear now in the framework of the V-model. The seismic moment release rate \( \dot{M}_s \) has no simple and explicit relation with subduction parameters that could be tested with the presently available data set.

7 CONCLUSION

The main purpose of this paper is to verify the model of viscous interseismic interaction of lithospheric plates at active margins assuming an elastic strain energy balance for interseismic and coseismic periods. The particular model used above to estimate the extremal values of interseismic displacement and energy accumulation is of course a crude approximation of the actual process taking place in subduction zones. Very important phases of the cycle of a great earthquake, pre-seismic and post-seismic, are not considered at all. Neither can the model describe the rupture process at the interface zone since this zone is assumed to be viscous.

Nevertheless the V-approach based on the assumption of sediment subduction yields physically reasonable relations between seismicity and global tectonic parameters that are supported by the data. This is feasible even for the seismic-slip or relative seismic-slip velocity. A surprising consistency with the main types of subduction zones and the asperity classification provides additional support for the model. Thus the subduction of sediments and their thickness at the trench is probably one of the most important factors governing seismicity and regional tectonics at active plate boundaries.

It will be of interest and great importance to understand the main reason for the general subdivision of all subduction zones into island arc- and continental arc-types. The V-model approach seems to be very useful for the purpose.

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REFERENCES


