Shallow subsurface imaging of the Wagad active fault system (Kachchh, northwestern India) by time domain electromagnetic studies

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The Kachchh rift basin (KRB) in the northwestern Indian shield is one of the most seismically active intraplate regions of the world. It has witnessed four large earthquakes in the past two centuries that leads the region most vulnerable for seismic hazard. For effective seismic hazard assessment, detailed information on faults and its subsurface geometry is essential. Recently, shallow subsurface geophysical studies, particularly electrical resistivity studies have become a successful practice in imaging of fault zones and their attribute. In the present study, we carried out the time domain electromagnetic (TDEM) investigations across the Wagad highland of eastern KRB to map shallow subsurface structure and imaging fault zones in terms of resistivity. Resistivity section obtained after combining one dimensional models of 21 sites display significant details of the fault structures and geometry of shallow basin infill down to 200 m. The shallow layer of the basin infill across the South Wagad fault (SWF) and the North Wagad fault has a wedge shape made of unconsolidated deposits with thickness of ~ 15 – 20 m. We infer that it might be due to syntectonic sedimentation due to the footwall subsidence across a branch fault of the SWF. The section indicates a ~ 60 – 65 and 50 – 55 m estimates of cumulative throws for the SWF and NWF, respectively. Across the Gedi fault, the section indicates least block displacements, which might either be due to dominate strike-slip nature of faulting or more activeness of NWF compared to GF during the recent geological past. The results from the study affirm the ongoing Holocene deformation in the region signifying active nature of these faults.

Keywords. Time domain electromagnetics; resistivity; active faults; Kachchh.

1. Introduction

The Kachchh rift basin (KRB) (figure 1) in the western most part of India is one of the most seismically active intraplate regions of the world (Kayal *et al.* 2002; Biswas 2005, 2016). The basin had experienced four large earthquakes in the past two centuries, which includes M 7.8 earthquake on the Allah Bund fault (1819); the M 6.3 earthquake on the Kachchh Mainland fault (KMF) (1845), the

M 6.1 Anjar earthquake (1956) and the widely destructive M 7.7 Bhuj earthquake (2001) on the step over fault zone near the South Wagad fault (SWF) (Rastogi *et al.* 2014; Talwani 2016). Many geophysical and geological investigations have been carried out after the 2001 earthquake. The studies inferred re-activation and branching of existing faults in the region (Biswas and Khattri 2002; Mandal *et al.* 2004, 2007; Biswas 2005; Patidar *et al.* 2007; Maurya *et al.* 2013; Rastogi *et al.* 2012,

Figure 1. Map showing geological setup of the Kachchh basin superimposed on topography of the region (modified after Biswas and Deshpande 1970). The TDEM sounding locations are shown with the diamond symbols. The stars represent the location of the 1819 and 2001 earthquakes.

2014), particularly in the eastern part of the KRB. The current aftershock activity has been attributed to activity along these fault systems. Deep geophysical investigations are being carried out to understand the nature of the faults and mapping blind faults across the basin (Kayal *et al.* 2002; Mandal *et al.* 2004; Chandrasekhar *et al.* 2009, 2012; Naganjaneyulu *et al.* 2010; Pavan Kumar *et al.* 2017a,b). However, the amount of shallow geophysical surveys done in the region is very limited (Mithila and Bansal 2016) except Ground Penetrating Radar (GPR) studies. It is of considerable importance to explore the geological structure around active faults, especially near-surface unconsolidated layers, to estimate the faults activity. The information on active faults and its subsurface geometry is essentially needed for effective seismic hazard assessment.

Many active fault traces were identified in the region based on field (both geophysical and geological) investigations and satellite photo interpretation, which suggested imprints of Holocene to post Tertiary tectonic activity along the faults (Malik *et al.* 2001; Mathew *et al.* 2006; Patidar *et al.* 2007, 2008; Maurya *et al.* 2013; Rajendran *et al.* 2008; Chowksey *et al.* 2011; Bhattacharya *et al.* 2013; Kothiyar *et al.* 2016). GPR studies by Patidar

et al. (2007) indicated reactivation of the Kathrol Hill Fault (KHF) under compressive stress and suggested southward directed tilting of the geomorphic features due to neotectonic movements along the KHF. Further, the study revealed the splaying nature of the fault in Quaternary sediments (Patidar *et al.* 2008). Mandal *et al.* (2004, 2007) on the basis of passive seismology studies, identified an E–W trending blind thrust, named as North Wagad Fault (NWF), which is suggested to be the causative fault for the 2001 Bhuj earthquake. A GPR study by Maurya *et al.* (2013) infers that the Gedi fault (GF) is steep north dipping reverse fault, which becomes vertical at depth and is characterized by the moderate earthquake activity under a compressive stress regime. Morphometric analyses of North Wagad Fault (NWF) and the GF zones (Bhattacharya *et al.* 2013) suggested that the past and current seismicity associated with both the NWF and GF. They further inferred that the NWF seems to be more active compared to the GF. Recent electromagnetic imaging studies by Pavan Kumar *et al.* (2016) along the Anjar-Rapar corridor infers the anomalous behavior of the aquifer in the KHF and the SWF zones.

Recent studies suggest that the eastern Kachchh is a potential zone for major earthquakes in the

near future (Biswas 2005; Rastogi *et al.* 2012; Mandal 2016; Pavan Kumar *et al.* 2017a,b). It is also evident from the concentration of earthquakes showing two prominent clustering around west and north of the Wagad region suggesting that this part of the basin is a highly strained zone with high seismic hazard potential (Mandal *et al.* 2007; Mandal 2016; Pavan Kumar *et al.* 2017a,b). The recognition and characterization of faults and its splays/branches in terms of geometry, type of movement and rates of activity are essential in understanding morphotectonics as well as assessing the seismic potential of a region. Identification of secondary faults, particularly assessment of their seismic potential, is sometimes difficult because of the poor conditions of surface exposure (concealment by bodies of water or young sediments, plastic deformation of near-surface materials). It is of considerable importance to geophysically explore the geological structure around the faults, especially subsurface unconsolidated layers, presence buried earthquake related structures for evaluation of activity along the fault. Further, for a realistic estimate of seismic hazard scenario, information on faults and its subsurface geometry (rupture length, dip and strike of fault) is essentially needed. In view of this, an attempt has been made to map the shallow subsurface resistivity structure between the SWF and GF in the Kachchh rift basin. We have applied time domain electromagnetic method (TDEM), which is an effective tool for exploring shallow subsurface structure down to several hundred meters, to image the lateral and vertical geological discontinuities across the fault zones and analyze in terms of activity of the region (Villani *et al.* 2015; Civico *et al.* 2017). Couple of deep electrical resistivity studies, particularly magnetotellurics (MT) surveys (Chandrasekhar *et al.* 2012; Pavan Kumar *et al.* 2017a,b) have been carried out in the region to understand the seismogenesis of the region as well architecture of the faults at crustal levels. However, the MT sections does not provide high resolution image at very shallow depths (down to 200–250 m). As the KRB has an average sedimentary (imaged as a conducting layer) thickness of >2 km (Pavan Kumar *et al.* 2017a,b), the sharp resistivity contrast across the fault zones (imaged as conducting zone) with in the sedimentary layers may not resolved using broadband MT surveys. We therefore carried out TDEM studies in the region for the well resolved resistivity structure across the fault zones at shallow depths. The surficial expressions of the faults

in some places of the Wagad region are concealed by recent Holocene deposits and difficult to image using conventional DC electrical imaging studies. The TDEM has proven to be an effective tool in mapping these concealed geological structures and can image the transposition of the various litho-units in terms of resistivity contrast (Pavan Kumar *et al.* 2016). Further, unveiling the nature of the shallow basin infill mainly from alluvial fans filling is very important in evaluating the role played by the active faults in its depositional evolution.

2. Geology and tectonics of the study area

North-south compression scenario in the KRB promotes reverse faulting on E–W faults and strike-slip motion on transfer faults (Biswas 2005; Talwani 2016). The region consists primarily of six E–W striking faults, which bound three uplifts, and a few NW–SE and NE–SW striking transfer faults (figure 1). The major structural features of the region are bounded by the south-dipping Nagar Parker Fault (NPF) and the north-dipping North Kathiawar Fault (NKF) (figure 1). Other major faults in this region are the Allah Bund Fault (ABF), Kachchh Mainland Fault (KMF), Katrol Hill Fault (KHF), Banni Fault (BF), Vigodi Fault (VF), South Wagad Fault (SWF), Gedi Fault (GF) and North Wagad Fault (NWF) (Biswas and Khattri 2002; Mandal *et al.* 2004) (figure 1). The uplifted terrains in the region are: (1) the Island Belt Fault Zone; (2) the Kachchh Mainland highland, and (3) the Wagad highland. The Island Belt Fault Zone comprises four islands, *viz.* Pachchham, Khadir, Bela and Chorar. These islands are inferred to be controlled and separated by the right-lateral transverse and strike-slip faults (Biswas 2005).

The Mesozoic rocks are exposed on the uplifted land masses, while Tertiary rocks have occupied the structure lows within the basin. The Quaternary/Tertiary sediments, Deccan volcanic rocks and Jurassic sandstones resting on the Archean basement characterize the geological sequence of the Kachchh region (Biswas and Deshpande 1970). These sediments have a zone of the Deccan trap volcanic sandwiched between Jurassic rocks of the northern part and Eocene sediments in the south towards the coast. Limestone, shale and sandstone are the most common rocks in the region (Merh 1995).

2.1 The Wagad highland and SWF zone

The Wagad region in the eastern Kachchh basin is delimited by the South Wagad Fault (SWF) in the south and Gedi fault (GF) in the north, and has a maximum elevation of >400 m (Biswas and Deshpande 1970). The region is suggested to comprise of several coupled active faults which reactivated after the 2001 Bhuj earthquake (Mandal 2016; Singh *et al.* 2016). Biswas (2005) inferred that the south dipping SWF is a step-over fault of the KMF in the east, was the source of the 2001 Bhuj earthquake. Seismicity distribution of the area shows that a large number of aftershocks (Mw 2.2–5.7) occurred in the Wagad area with focal depths ranging from 10 to 40 km (Singh *et al.* 2016). Lithologically, the terrain is dominated by Jurassic and Cretaceous sandstone, shale and limestone with some outcrop of Tertiary limestone and sandstone in the north and southeast of Wagad (Biswas and Deshpande 1970).

The southern part of the highland, demarcated by the SWF zone is much faulted and appears to have been fragmented into several wedge blocks bounded by converging and diverging faults (figure 2) (Kothyari *et al.* 2016). The

geometry of the SWF zone is very complex due to crustal shearing on both sides of the main fault (SWF) and several domes and anticlinal structures have developed within the fault zone. The upthrown block of the zone has Cretaceous shale, sandstone and glauconitic and micaceous sandstone and the foot wall comprises shale interbedded with marl and miliolitic limestone of Cenozoic-Tertiary age (Kothyari *et al.* 2016).

In the western part of the highland, two fault branches of SWF are the Adhoi and the Kanthkot faults. The Chitrod and Khanpar faults lie in the central part (figure 2). Several other branches faults, namely Lakadiya, Lakhiasar, Kidiyanagaru and Kanmer faults (Biswas 1993; Kothyari *et al.* 2016) faults are mapped in the region and are inferred to be developed due to reactivation of SWF. These faults are collectively called the South Wagad Fault (SWF) system (Kothyari *et al.* 2016). The faults are inferred to be both synthetic and antithetic to the SWF. It is also observed that most of these younger faults were activated after the 2001 main shock (Kothyari *et al.* 2016). Talwani and Gangopadhyaya (2003) opined that the presence of intersecting fault zones, particularly in the stable continental region could represent the

Figure 2. Topographic map of the Wagad highland and its surrounding areas with major faults. (The branch faults of the SWF are taken from Biswas 2016). The TDEM sites are shown with stars.

zones of stress accumulation and might be probable location for strong earthquakes.

3. TDEM field survey and data processing

We carried out the fixed in-loop TDEM soundings at 21 sites in the eastern part of the Kachchh basin (figure 1) for mapping shallow-subsurface structure and distinct lateral and vertical geological contacts in terms of electrical resistivity. The survey transect crosses the various geological terrains bounded by faults, e.g., SWF, NWF and GF (figures 1 and 2). We used Zonge (USA) made data acquisition system comprises the GDP-32 receiver, transmitter (ZT-30), transmitter controller (XMT) and a receiver antenna. During the TDEM survey, a primary electromagnetic field is generated by a 100 m sided transmitter loop (single turn) laid on the ground, through which alternating current of 9.2 amp is passed with equal periods of time-on and time-off, at various frequencies ranging from 1 to 32 Hz (Nabighian and Macnae 1991; McNeill 1994). A receiver located near the center of the transmitter loop recorded the secondary vertical magnetic fields (Hz) in terms of the induced voltage (in nanovolts/m²) during the time-off period at 31 discrete time intervals ranging from a few μ s to a few ms. The window lengths for the different transmitter frequencies are listed in table 1.

Several transient decay measurements are made, and the measurements are stacked to improve signal to noise ratio. To reduce the influence of EM noise, the recorded transients are stacked over a number of cycles (512, 256 and 128 cycles) (Mills *et al.* 1988; Goldman *et al.* 1991; McNeill 1994). We recorded data at 32, 16 and 8 Hz (high frequencies) currents for shallow depths and low frequencies (4, 2 and 1 Hz) for deep probing.

Apparent resistivity is computed from the recorded voltage (magnetic field) in the receiver

coil and the current injected into the transmitter loop (equation 1). Apparent resistivity at late times can be calculated using the formulae (Nabighian and Macnae 1991)

$$\rho_a = \left(\frac{IA_T A_R}{V} \right)^{2/3} \left(\frac{1}{t} \right)^{5/3} * 6.3219E - 3 \Omega\text{m}. \quad (1)$$

A_T and A_R are the transmitter and receiver moments in square meters, I is the transmitter current, V is the voltage in microvolts, t is time in milliseconds and ρ_a is the apparent resistivity in Ωm . In general, early time windows may have been saturated (same or similar magnitudes for the first few windows). We removed the early-time saturated windows as well as late-time noise windows (Civico *et al.* 2017). The decay curves at various transmitter frequencies (32, 16, 8, 4, and 2 Hz) and corresponding apparent resistivity curves as a function of time for 20 sites along the profile are shown in figure 3.

4. One dimensional (1-D) inversion

The measured transient decay and estimated apparent resistivities are used to model the depth and subsurface resistivity of the underlying structure. We choose the processed data at 4 Hz transmitter frequencies as the data are less erroneous at late times (>10 ms). The good quality late time data can give deeper information and for too low frequencies, the late time data are many times noisy due to energy dissipation. To maintain the trade-off between deeper information and quality of the data we have chosen the data at 4 Hz transmitter frequency with time interval of 62.5 msec to accurately measure the late time transient amplitudes. One dimensional inverse modelling is performed considering the horizontally layered earth model with homogeneous and isotropic layers (Mills *et al.* 1988). Topographic variations across the profile are incorporated during the inversion routine. To have a slight better near surface resolution for the central loop soundings, we used intermediate to late time gates and omitted first biased gates from the offset measurements due to sign reversal or the anomalous decay of the secondary magnetic field (Villani *et al.* 2015).

For the present study, we used STEMINV (Zonge, USA) program to estimate layered-earth resistivity models. The algorithm uses an iterating

Table 1. The windows lengths for the different transmitter frequencies.

Sl. no.	Frequency	50% Duty cycle	
		First (μ s)	Last (ms)
1	32	30.5	6.07
2	16	30.5	12.1
3	8	30.5	24.2
4	4	30.5	48.4
5	2	61.0	96.7
6	1	121.1	193.5

Figure 3. Transient decay and the computed apparent resistivity curves for twenty sites along the profile.

best-fit algorithm to minimize the RMS residuals between the observed and calculated rate of magnetic field reflected as the induced voltage for each station to determine the parameters of a layered-earth model. After generating the initial model, data points that are either anomalous or could

not fit to any earth model due to large error bars are selectively discarded from the voltage *vs.* time decay curve. After removing the anomalous points, the inversion is re-executed to create the best possible model. Total RMS error is calculated using the formula (MacInnes and Raymond 2001)

Figure 3. (Continued.)

$$\varepsilon_{\text{total}} = \sqrt{(\varepsilon_{\text{data}}^2 + \varepsilon_{\text{model}}^2) / n_{\text{obs}}},$$

$$\varepsilon_{\text{data}}^2 = \sum_{i=1}^{n_{\text{obs}}} \left(\frac{d_{o_i} - d_{m_i}}{d_{\text{err}_i}} \right)^2,$$

$$\varepsilon_{\text{model}}^2 = dpW^2 \sum_{j=1}^{nz} \left(\frac{p_j^k - p_j^o}{p_{\text{err}_j}} \right)^2 + dzW^2 \sum_{j=2}^{nz} (p_j^k - p_{j-1}^k)^2.$$

Figure 4. Figure showing the site wise RMS errors.

Here, n_{obs} is the number of observed data values and n_z is the number of layers per station in inversion model. d_{o_i} and d_{m_i} are the observed and calculated data (dB/dt), respectively. d_{err_i} and p_{err_j} are the observed data error and inversion model error respectively. p_j^o and p_j^k are stating model parameter [$\log(\text{resistivity})$] and model parameter after k th iteration respectively. dpW and dzW are the relative weight given for starting model and vertical smoothness constraint, respectively.

The total RMS error between observed and modelled TDEM response are less than 2.0 for most of the sites. The total RMS error for each site is shown in figure 4. The observed and calculated, along with model parameters (resistivity and depth) for 18 sites are shown in figure 5.

5. Results and discussion

One dimensional inversion models of all 21 sites are used to create color-filled resistivity section (figure 6) across the profile. The average RMS error for the section is 1.60. The resistivity section shows significant variations of shallow resistivity values across the fault zone(s) down to 200 m revealing complex shallow structure of the Wagad region. We have marked the surface locations of the various active faults (Mandal *et al.* 2007; Bhattacharya *et al.* 2013; Kothiyari *et al.* 2016) in the resistivity section (figure 6).

The resistivity values ($\sim 100 \Omega\text{m}$) observed in the southern part of the section up to site 8 suggest the presence of Mesozoic rocks in the Wagad region composed of Wagad sandstone and shale (figure 6). Interestingly, a moderate conducive medium at site 4 and slightly dipping south is observed within the Mesozoic. Previous geological studies by Kothiyari *et al.* (2016) inferred normal faulting in the Mesozoic near the south and north of the Chitrod village and named them as Khanpar fault (KF) and Chitrod fault (CF) (figure 2), respectively, which are considered as a branch faults of the SWF. We

infer that the conducive zone below site 3 and 4 could indicate the presence of the Chitrod fault (CF). The faulted blocks are clearly reflected in resistivity section with $100 \Omega\text{m}$ on either side of the fault zone (figure 6). The resistivity section clearly demarcates the upthrown and downthrown blocks of the CF. The upthrown block is made up of Cretaceous shale, sandstone and glauconitic and micaceous sandstone and the downthrown block has the shale interbedded with marl and miliolitic limestone of Cenozoic-Tertiary age (Kothiyari *et al.* 2016). The contact zone might be representing the presence of infill material within the two faulted blocks. We attempted to calculate cumulative vertical throw of the SWF and other faults from the obtained resistivity structure of the across the fault zone (figure 6).

5.1 SWF

The shallow layer of the basin infill across the SWF zone (composed of Khanpar and Chitrod normal faults) has observed to be wedge shaped. The resistivity of the infill material with thickness $\sim 15\text{--}20$ m is less than $20 \Omega\text{m}$. We infer that the zone might comprise unconsolidated river deposits (fluvial sediments). We suggest that the deposition of sediments within the wedge might represents the syntectonic growth of the alluvial-fan, filling the accommodation space provided by the hanging wall subsidence. Considering the present day elevation, we estimate a cumulative throw of $60\text{--}65$ m for the SWF splays, i.e., KF and CF; taking into account the difference of basement elevation of the footwall and hanging wall. Based on TDEM soundings, we suggest that the basement rock occurs at $\sim 75\text{--}80$ m depth in the footwall of the KF (figure 6).

5.2 NWF

Based on surface geological investigation, McCalpin and Thakkar (2003) have imaged a major morphological features in the Bharudia and named it as Bharudia fault, later described by Mandal *et al.* (2004) as the North Wagad Fault (NWF) zone. The fault is inferred as a sinuous hanging wall collapse scarp, where the northern part of the scarp is buried by the Quaternary deposits. The sharp resistivity contrast observed across the sites 8 and 9 suggests the contact zone of Mesozoic and Tertiary formations probably representing the presence of the NWF. The fault zone comprises the Tertiary deposits with small content of

Figure 5. Observed magnetic field values for 18 sites (short horizontal dash and a vertical error bar) along with data (solid black) estimated by the model obtained from inversion (right panel). Omitted data are shown in red.

clay or/and groundwater. The disposition/vertical off set of the two fault blocks is estimated to be about 55–60 m across the fault zone, which is significantly less compared to the SWF (figure 6). It was opined the NWF is reactivated after the 2001 Bhuj earthquake (Mandal *et al.* 2007; Mandal 2016), the cumulative throw of the fault blocks

is observed to be less compared to the branch fault of SWF. However, the sedimentary deposition over the NWF zone is observed to be high (>20 m) compared to the SWF (figure 6) zone strengthening the previous observations that the fault has been buried over the Quaternary sediments. Greater Quaternary deposits might also

Figure 5. (Continued.)

indicate the greater activity of the NWF in recent past compared to the branch faults of the SWF.

5.3 Gedi fault

The sharp resistivity contrast of observed across the sites 10, 11 and 12 in the delineated section corresponds to the Gedi fault, which separates the

younger and older formations, i.e., Quaternary to Tertiary. The low resistivity zone is likely related to the fault fractured zone with high content of fluids (probably water at shallower depths) (Electromagnetic Research Group 1982). The wide low resistive zone observed in the section is possibly caused by relatively low degree of fracture, whereas the extremely high conducting band seems

Figure 5. (Continued.)

associated with the fault plane, along which clay minerals have developed along the fractured zone. Further, the Gedi fault zone is very close to the Rann of Kachchh, there is a possibility of infiltration/saturation of the fracture zone with marine water having high salinity along with deposition of clay. The vertical disposition of blocks could

have attributed to the dominate strike-slip nature of faulting across the GF. Across the GF, the derived resistivity section indicates least block displacements (45–50 m) (figure 6). The small vertical disposition of blocks could have attributed to either due to dominate strike-slip nature of faulting in addition to normal or more activeness of

Figure 6. Near surface resistivity section across the SWF and GF zones.

Figure 7. Seismicity (during 2008–2015) distribution map across the Bela island.

NWF compared to GF during the recent geological past. Similar to NWF, the GF is inferred to be reactivated (Bhattacharya *et al.* 2013) after the Bhuj earthquake. However, data at grid pattern around the GF could give better information on the lateral lithological changes across the fault zone.

5.4 Rann sediments

The low resistivity values observed in northern part of the Gedi fault infers the Quaternary sedimentary formations, mainly of mud and salt-flats (Rann sediments) between sites 13 to 19 (figure 6). The Rann sediments are observed as highly conductive ($<5 \Omega\text{m}$) zone in the entire depth section. However, a comparatively less conductive zone ($\sim 10 \Omega\text{m}$) is observed between the sites 13 to 15. We infer that this could be an aquifer zone within the Tertiary deposits, trapped in-between the two uplifted terrains. However, the presence of the aquifer zone

and its linkage with any paleochannels of the region is needed to be studied in detail.

Between sites 4 and 5, we observe a moderate conductive zone within the foot wall of the SWF/CF block. In view of continued seismicity of the region and active deformation of the Wagad uplift, we opined that this moderately conductive zone might be representing a fractured zone within the highland. However, some more TDEM points are required to further characterize the zone. In the northern most part of the profile, we observe another resistivity contrast reflecting the geological contact between the Rann-sediments and the Bela uplift that composed of Mesozoic. The Bela island bounded by IBF at the north and GF at its south. The Bela island suggested be northerly uplifted and dipping towards the GF (Biswas 2016). High seismic activity (figure 7) in the southern Bela unit and elevation differences suggest the activeness of these faults. We, therefore, speculate that

the geological contact could be considered as a branch fault of GF developed due to the rupture created by the seismic activity on southern Bela highland.

From the resistivity model (figure 6), it is evident that the traces of the SWF and GF are seen up to the surface. This affirms that these faults are responsible for the ongoing Holocene deformation in the region, suggesting the active nature of the faults. The significant heterogeneities across the SWF and GF zones in the shallow subsurface levels as observed in deep geophysical studies (Mandal 2016; Singh *et al.* 2016; Pavan Kumar *et al.* 2017a, b) could be responsible for the accumulation of large crustal strain that results in high seismic activity in the KRB. However, the buried and active nature of the faults in terms of seismicity needs deep geophysical studies, particularly magnetotellurics investigation to map and understand the deep architecture of the fault zone.

6. Conclusions

Resistivity section obtained after combining one dimensional models of the 21 sites acquired across the various fault zones in the eastern Kachchh basin suggests the significant variations of shallow resistivity values across the fault zone(s) down to 200 m. The shallow layer of the basin infill across the SWF and NWF has a wedge shape and represent the ongoing syntectonic sedimentation due to the movement of the fault blocks. The resistivity model indicates a minimal ~60–65 m, and 50–55 m estimate of the cumulative throw of the SWF and NWF, respectively in the investigated section. Across the GF, the derived resistivity section indicates least block displacements compared to the NWF zone, indicating more activeness of NWF compared to GF. The results from the study affirms the ongoing Holocene deformation in the region signifying the active nature of the faults, which is also supported by deep and shallow geophysical constrains. Interdisciplinary studies, including shallow geophysical, geomorphological and paleoseismological studies are essential to characterize the active faults in the area and precise subsurface studies shall document the successive tectonic events and related landform development. The study highlights the efficacy of the TDEM studies in structural geology and morphotectonic studies in the active intraplate region.

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