# 2 Geološki razvoj Slovenije – Povzetek
# Geological Evolution of Slovenia – An Overview

# 2 GEOLOŠKI RAZVOJ SLOVENIJE – POVZETEK
# GEOLOGICAL EVOLUTION OF SLOVENIA – AN OVERVIEW

Marko VRABEC[1], Andrej ŠMUC[2], Mario PLENIČAR[3] & † Stanko BUSER

## UVOD

Ozemlje Slovenije leži na stičišču geotektonskih enot Dinaridov, Južnih Alp, Vzhodnih Alp in Panonskega bazena. Te velike strukturne enote imajo različno paleogeografsko in tektonsko zgodovino, poleg tega pa mlajši strukturni sistemi (npr. prelomi in tektonski jarki Panonskega bazena) prekrivajo starejše. Današnja geološka zgradba in razpored strukturnih enot na ozemlju Slovenije sta nastala pretežno šele v neogenu, v zadnjih 20 milijonih let, aktivni tektonski procesi pa se nadaljujejo tudi danes.

Paleogeografsko pripadajo vse strukturne enote slovenskega ozemlja Jadranski litosferski plošči, ki kot samostojna kontinentalna plošča obstaja od mezozoika do danes. Južni rob Jadranske plošče se je prvotno držal Afriške plošče na območju današnje Libije. Kolizija Jadranske plošče z Evropo v terciarju je povzročila nastanek Alp in je bila glavna gonilna sila tektonskih procesov, ki so oblikovali današnjo zgradbo slovenskega ozemlja. Kompleksna paleogeografija mezozojskega oceanskega prostora Tetide med Afriško in Evrazijsko ploščo je zelo slabo ohranjena zaradi poznejših premikov ter subdukcijskih in kolizijskih tektonskih procesov.

## PALEOZOIK

Najstarejše s fosili dokazane sedimentne kamnine na Slovenskem so bile najdene v prodnikih permokarbonskega konglomerata vzhodno od Ljubljane. To so ortocerasni apnenci zgornjesilurske starosti, nastali pred približno 420 milijoni let. Paleogeografske rekonstrukcije tega obdobja uvrščajo naše ozemlje bodisi na severni rob takratne celine Gondwane, ki so jo sestavljale današnje Afriška, Južnoameriška, Avstralska in Antarktična plošča, bodisi na samostojno kontinentalno ploščo v oceanu Paleotetida med Gondwano na jugu in Lavrusijo, ki so jo sestavljale današnje Severnoameriška plošča, Evropska plošča in Ruska plošča na severu. Sedimentološke značilnosti kamnin in stratigrafskih zaporedij kažejo na odlaganje na kontinentalnem robu.

### Devon

Devonski apnenci se pojavljajo v Južnih Karavankah med Logarsko dolino in Jezerskim. Spodnjedevonske plasti so in-

[1] Marko VRABEC, Oddelek za geologijo, Naravoslovnotehniška fakulteta, Univerza v Ljubljani, Privoz 11, SI-1000 Ljubljana, marko.vrabec@ntf.uni.-lj.si

[2] Andrej ŠMUC, Oddelek za geologijo, Naravoslovnotehniška fakulteta, Univerza v Ljubljani, Privoz 11, SI-1000 Ljubljana, andrej.smuc@ntf.uni.-lj.si

[3] Mario PLENIČAR, Slovenska akademija znanosti in umetnosti, Novi trg 3, SI-1000 Ljubljana.

## INTRODUCTION

The territory of Slovenia spans the junction between four major Alpine structural units, each with an independent paleogeographic and tectonic history: the Dinarides, the Southern Alps, the Eastern Alps, and the Pannonian Basin. The present-day assemblage and geological structure of these structural units was mainly formed in Neogene times, during the last 20 Ma of Earth's history. Tectonic processes, related to Alpine collision, continue to be active up to the present.

Paleogeographically, the structural units of Slovenia belong to the Adriatic continental microplate (or Adria). Prior to the Mesozoic, the Adriatic fragment was attached to the African plate in the area of present-day Libya. Tertiary collision of Adria with Eurasia produced the Alpine orogenic chain and was the tectonic driving force that shaped the present-day structure of Slovenian territory. The complex paelogeography of the Tethys oceanic domain and its margins that formerly existed between the African and Eurasian plate was largely obscured by subsequent subduction and collisional processes.

## PALEOZOIC

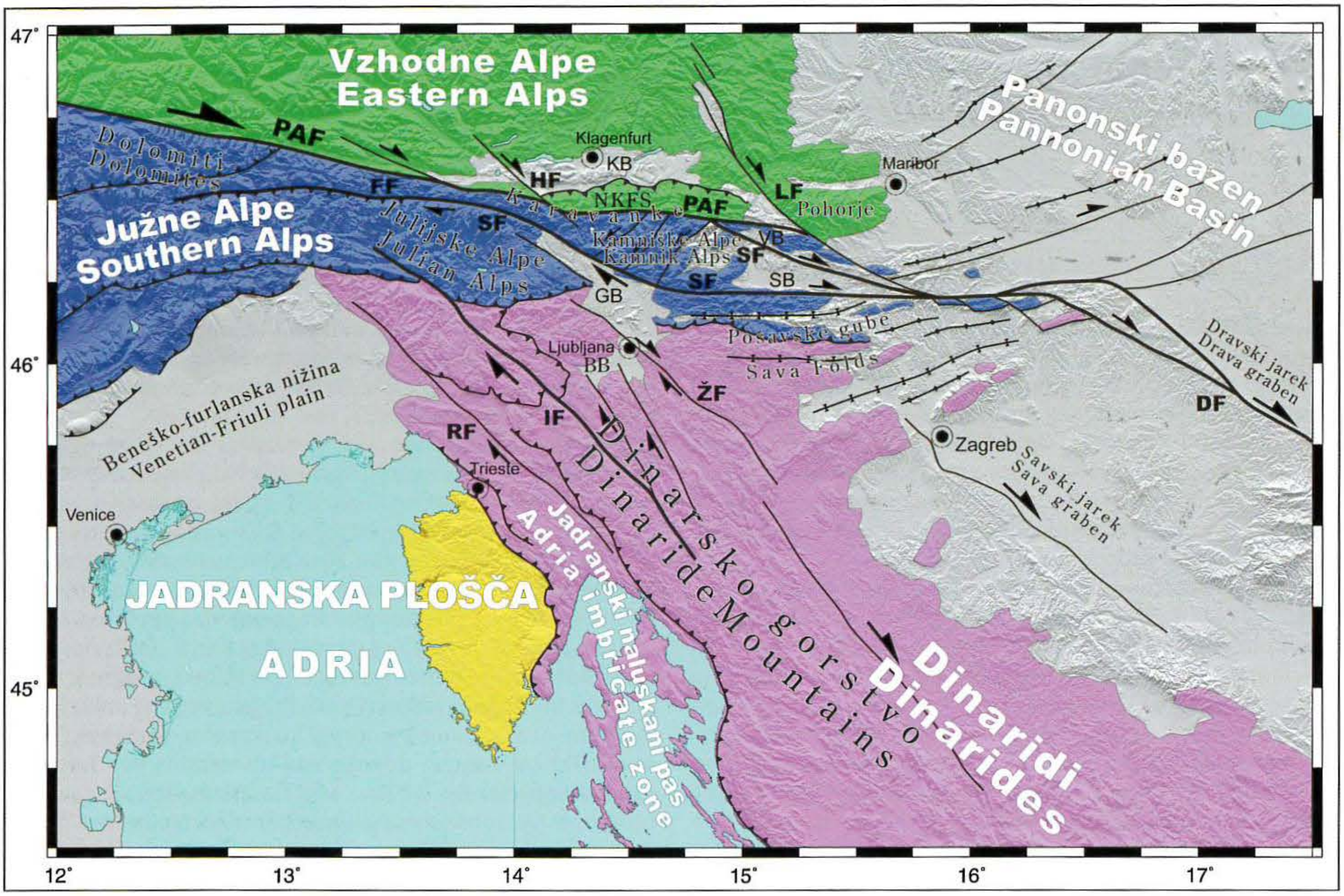
The oldest known sedimentary rocks in Slovenia are found as pebbles in Permo-Carboniferous conglomerates outcropping east of Ljubljana. These clasts were derived from the 420 Ma old Upper Silurian Orthoceras limestone.

In modern paleogeographical reconstructions for that time, the precursor litospheric basement that eventually became the present-day territory of Slovenia is placed either on the northern margin of Gondwana, or onto an independent continental strip in the Paleothetys ocean, which existed between Gondwana and Laurussia. Characteristics of the Paleozoic sedimentary succession suggest deposition on the continental margin.

### Devonian

Devonian limestones occur in the Southern Karavanke mountains between Logarska dolina and Jezersko. Lower Devonian beds are interpreted to have been deep-water sediments. By Mid-Devonian times, beds were being deposited on a shallow carbonate platform with coral reefs. By the end of the Devonian, a drop in sea level attributed to global eusatic lowstand subaerially exposed the carbonate platform, causing erosion and karstification.

Rocks of the Pohorje, Strojna and Kozjak massifs in northeastern Slovenia probably also originated in this part of the




Sl. 2.1. Pregledna tektonska karta severovzhodnega dela kolizijske cone med Jadransko in Evropsko tektonsko ploščo z glavnimi geografskimi značilnostmi. Prirejeno po: VRABEC & FODOR, 2006.

Legenda: KB – Celovški bazen; HF – Prelom Stola; PAF – Periadriatski prelom; FF – Fella prelom; SF – Savski prelom; ŠF – Šoštanjski prelom; VB – Velenjski bazen; SB – Savinjski bazen; GB – Gorenjski bazen; LF – Labotski prelom; BB – Barjanski bazen; ŽF – Želimeljski prelom; IF – Idrijski prelom; RF – Raški prelom; DF – Dravski prelom.

Fig. 2.1. Simplified tectonic map of the north-eastern corner of the Adria-Europe collision zone with principal geographic features. Modified after: VRABEC & FODOR, 2006.

Explanation: KB – Klagenfurt basin; HF – Hochstuhl fault; PAF – Periadriatic fault; FF – Fella fault; SF – Sava fault; ŠF – Šoštanj fault; VB – Velenej basin; SB – Savinja basin; GB – Gorenjska basin; LF – Lavanttal fault; BB – Barje basin; ŽF – Želimlje fault; IF – Idrija fault; RF – Raša fault; DF – Drava fault.

terpretirane kot globljevodne, v srednjem devonu pa je sedimentacija potekala v okolju plitve karbonatne platforme s koralnimi grebeni. Proti koncu devona je bila, domnevno zaradi globalnega upada morske gladine, karbonatna platforma nekaj časa okopnjena, kar je povzročilo erozijo in zakrasevanje njenega površja.

Iz tega dela paleozoika verjetno izvirajo tudi kamnine Pohorja, Strojne in Kozjaka, ki so bile nato v več stopnjah srednje do visoko metamorfozirane, še posebno močno v obdobju krede. V najbolj šibko metamorfoziranih členih, ki jih tvorijo skrilavci z lečami marmoriziranih apnencev in kvarcitov, vsebujejo pa tudi diabaze in njihove tufe, so bili ponekod v Avstriji in pri nas namreč najdeni fosili ordovicijske, silurske in devonske starosti. Te kamnine raziskovalci večinoma uvrščajo v globljevodne, ki so se odlagale na prehodu med kontinentalnim robom in oceanskim dnom.

Paleozoic. Subsequently they underwent a multistage mid- to high grade metamorphism, which was particularly intense in the Cretaceous. However, in the most weakly metamorphosed members, schists with lenses of quartzite, marble, diabase and tuffs, fossil remains of Ordovician, Silurian and Devonian age are found in Slovenia and Austria. These rocks are believed to have been deposited in a deep-water environment at a transition from the continental margin and abyssal plain.

**Carboniferous**

Slovenia's rocks next record a deepening of the depositional environment in the Early Carboniferous that reflects the onset of the Variscan orogeny. The flysch-like Hochwipfel beds consist of shales, sandstones and grauwackes, and were deposited in foreland basins. Today they outcrop around Jezersko in the Karavanke mountains. A short-lived volcanic event is

**Karbon**

V devonu in karbonu je potekala varistična orogeneza, ki jo je povzročilo primikanje in končno kolizija Lavrusije in Gondwane. Varistično gorovje se je raztezalo od današnje Severne Amerike preko Evrope do Rusije. Na našem ozemlju so se ta orogenetska dogajanja izrazila s poglabljanjem sedimentacijskega prostora v spodnjem karbonu. V kompresijskih bazenih so se odlagale flišu podobne hochwipfelske plasti, ki jih sestavljajo skrilavi glinavci, peščenjaki in drobe. Najdemo jih v okolici Jezerskega. O kratkotrajnem vulkanskem delovanju pričajo porfiroidne vulkanske breče in tufi. Glavno fazo orogeneze in verjetni dvig kolizijskega orogena naznačujejo deformacije sinorogenih spodnjekarbonskih sedimentov, ki jih seka srednjekarbonska erozijska diskordanca. Nad varistično diskordanco so odloženi zgornjekarbonski postorogeni kontinentalni sedimenti molasnega tipa s kremenovimi konglomerati, peščenjaki in skrilavimi glinavci. Na močvirsko okolje sedimentacije kažejo ostanki praprotnic, preslic in lisičjakovcev, najdeni v Karavankah in Posavskih gubah. Drugje so se ob kontinentalnih odlagali tudi plitvomorski sedimenti Auerniške formacije, ki vključujejo tudi plasti apnenca.

**Perm**

V spodnjem permu se je v obrežnem pasu šelfa nadaljevala mešana karbonatno-siliciklastična sedimentacija, proti odprtemu morju pa so mahovnjaki, morske lilije in alge gradili robne grebenske kope, katerih pobočja so naseljevali številni ramenonožci. Znano najdišče fosilov v teh apnencih je Dovžanova soteska pri Tržiču. V zaledju kop so bili v lagunah odloženi črni plastnati apnenci z velikimi fuzulinidnimi foraminiferami. Grebenska sedimentacija masivnih trogkofelskih apnencev se je nadaljevala vse do konca spodnjega perma, ko jo je prekinila Saalska orogenetska faza. Zanjo so značilni vertikalni premiki blokov ob strmih prelomih, na kar kažejo ostre lateralne spremembe v debelinah formacij kakor tudi različna globina prodora erozije.

indicated by the presence of porphyritic volcanic breccias and tuffs. The main pulse of the Variscan orogeny, which was likely accompanied by uplift of a collisional orogen, is marked by the deformation of a synorogenic Lower Carboniferous package of foreland basin sediments and their truncation by a Mid-Carboniferous erosional unconformity. Above this Variscan unconformity, Upper Carboniferous postorogenic molasse-type sediments were deposited. These rocks are quartz conglomerates, sandstones and shales. A swampy continental depositional environment is indicated by the fossils of ferns, calamites and lycopods, found in the Karavanke mountains and in the Sava Folds. In other areas, shallow-marine beds of the Auernig Formation, which include limestones, were deposited as equivalents to these continental sediments.

**Permian**

In the Early Permian, mixed carbonate-siliciclastic sedimentation continued on a coastal shelf, bordered by marginal reef mounds built of bryozoans, crinoids and algae. An excellent locality containing abundant Early Permian fossils is Dovžanova soteska in the Karavanke mountains. In associated back-reef lagoons, beds of black limestones with large fusulinid foraminifera were being deposited. Sedimentation of the massive Trogkofel reef limestones continued up to the end of the Early Permian, when it was terminated by the Saalian orogenic event. The Saalian event is characterized by vertical block motions along steep faults, which are inferred from abrupt lateral changes in formation thicknesses, and the varying depths of erosion into pre-Saalian deposits.

The Saalian event was followed by continental sedimentation of the Middle Permian Tarvis breccia and Val Gardena beds, which are comprised of conglomerates, sandstones, siltstones and mudstones. The Val Gardena clastics were deposited in aluvial fans, rivers, and partly in a shallow marine environment. Their prevailing reddish coloration indicates an arid climate during their sedimentation. The Lower Middle Permi-

Sl. 2.2. Zapletena geološka zgradba Karavank je nastala z izrivanjem in narivanjem tektonskih blokov ob strmih prelomih pri krčenju ozemlja v pliocenu. Gorski hrbet Košute s Tržičem v ospredju. *Igor Košir*

Fig. 2.2. Complicated geological structure of the Karavanke mountains formed in uplifting and thrusting of tectonic blocks along sub-vertical faults during shortening in Pliocene. Košuta mountain ridge with the town of Tržič in the front. *Igor Košir*

Saalski fazi sledi kontinentalna sedimentacija. Na erozijski diskordanci ležijo srednjepermske trbiške breče in grödenske plasti konglomeratov, peščenjakov, meljevcev in glinavcev, odloženih v aluvialnih vršajih in rekah ter deloma tudi v plitvomorskem okolju. Značilna rdeča barva teh, tudi preko 1500 m debelih skladov kaže na aridno podnebje. V sivih in zelenkastih grödenskih klastičnih kamninah iz spodnjega dela srednjega perma je uranovo rudišče Žirovski Vrh. Le ponekod na ozemlju današnjih Julijskih Alp najdemo iz tega obdobja tudi plitvomorske grebenske apnence s foraminiferami neoschwagerinami.

V zgornjem permu je na območju celotne današnje Slovenije nastal plitvovodni morski sedimentacijski prostor – ***Slovenska karbonatna platforma***. Grödenske kontinentalne plasti tako navzgor zvezno prehajajo v zgornjepermske temnosive plastnate apnence plitvega šelfa, imenovane Žažarska formacija. Del teh apnencev je bil pozneje dolomitiziran, tako da najdemo v Južnih Karavankah in Posavskih gubah plastnat dolomit. Za to zaporedje je značilno tudi nastajanje evaporitov, ki so pri nas navzoči pri Dovjem v obliki sadre.

Varistični orogenezi je sledil postkolizijski magmatizem, ki mu pripisujejo nastanek železnokapelskega sienogranita zgornjepermske starosti. Pri nas to kamnino najdemo pri Črni na Koroškem. Ob koncu paleozoika so bile po zaporednih kolizijah vse kontinentalne plošče združene v en sam superkontinent z imenom Pangea. Vzhodno od območja Jadranske plošče se je razprostiral obsežen oceanski prostor - Paleotetida.

## MEZOZOIK

V Sloveniji so najbolj razširjene kamnine mezozojske starosti. Paleogeografsko kamnine pripadajo severnemu robu Jadranske litosferske plošče, ki je bila na zahodu in severu omejena z Alpsko Tetido oz. Piemont-Ligurijskim oceanom, na vzhodu pa jo je omejeval Vardarski ocean. V triasu in juri je kontinetalni rob doživel dve glavni fazi ekstenzijske tektonike, v kredi pa so celotno območje zajele kompresijske razmere, ki trajajo še danes.

### Trias

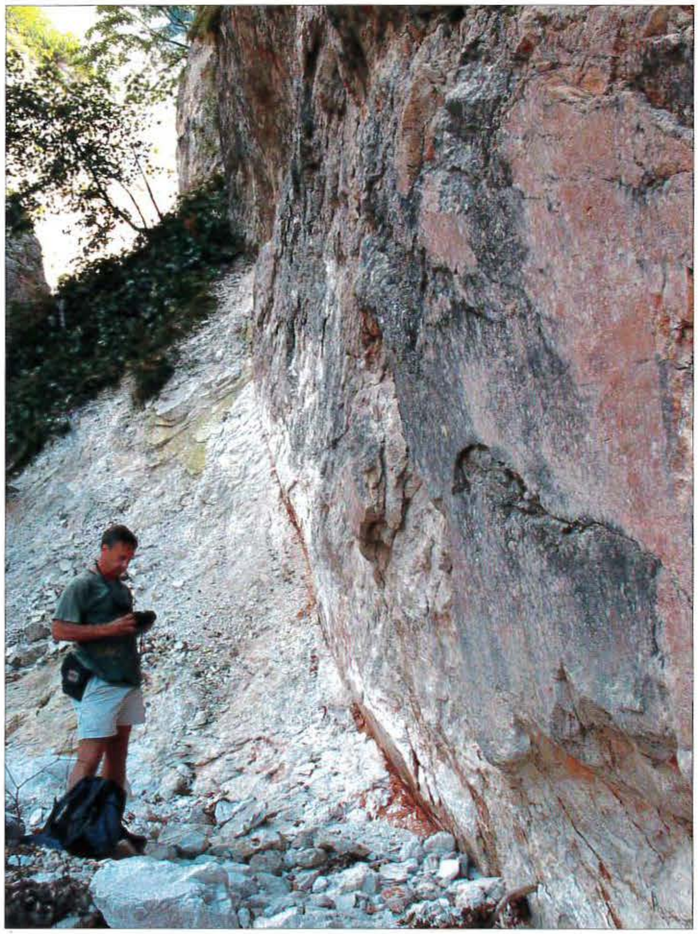
Plitvomorska sedimentacija se je na Slovenski karbonatni platformi iz perma nadaljevala v **spodnji trias**. Odlagali so se mešani siliciklastično-karbonatni sedimenti Werfenske formacije (peščenjaki in pisani sljudni laporji s številnimi fosili ter različne karbonatne kamnine, med katerimi so značilni rdeči oolitni apnenci). Izjema so le kamnine Karavank, Pohorja in Kobanskega, ki jih predstavljajo kontinentalni rdeči peščenjaki in glinavci. V **aniziju** se je vnos terigene komponente ustavil in na celotni Slovenski karbonatni platformi so začeli nastajati plitvovodni apnenci, ki so pozneje prešli v dolomite, redkeje pa grebenski in algni apnenci.

V obdobju **srednjega triasa** se je ob robu Evrazije začel odpirati nov ocean, Meliata. S tem dogodkom je povezana faza ekstenzije v **srednjem aniziju in ladiniju**, ki je prekinila sedimentacijo na Slovenski karbonatni platformi. Spremljajoči intenzivni vulkanizem, ki se je razvijal od začetnega ki-

an Val Gardena beds at Žirovski Vrh contain an economically important uranium deposit. Sporadic remains of Middle Permian shallow-marine reef limestones with Neoschwagerinid foraminifera can be found in the present-day Julian Alps.

In the Late Permian, the entire proto-Slovenia territory was drowned by a shallow sea. This event marks the birth of the ***Slovenian Carbonate Platform***. The underlying Val Gardena clastics gradually give way to dark-grey bedded limestones of the Žažar Formation. Since a part of the Žažar Formation was subsequently dolomitized, Upper Permian bedded dolomites occur in the Southern Karavanke and in the Sava Folds. The Upper Permian succession is also characterized by the deposition of evaporites. Gypsum occurences near Dovje are the most typical.

The Variscan orogeny was followed by post-collisional magmatism. The origin of the Late Permian Eisenkappel syenogranite, outcropping near Črna na Koroškem, is attributed to this magmatic episode.



Sl. 2.3. Izdanek prelomne ploskve Ravenskega preloma pod Tolminskim Migovcem v Julijskih Alpah. Desni premik ob tem prelomu je v letih 1998 in 2004 povzročil močna potresa v Posočju. *Marko Vrabec*

Fig. 2.3. Outcrop of the fault plane of the Ravne fault under Tolminski Migovec in the Julian Alps. Dextral slip along this fault has triggered two major earthquakes in Soča river region in 1998 and 2004. *Marko Vrabec*

slega prek srednjega do bazičnega, nakazuje začetek procesa razpiranja skorje (riftinga) tudi na našem območju, ki pa se je kmalu ustavil. Srednjetriasna ekstenzija je povzročila razpad enotne karbonatne platforme na ločene tektonske bloke, ki so se različno hitro pogrezali.

Ozemlje Slovenske karbonatne platforme je razpadlo na tri v regionalnem smislu prepoznavne paleogeografske enote. To so ***Julijska karbonatna platforma*** na severu (kamnine današnjih južnih Karavank, Julijskih in Kamniško-Savinjskih Alp), ***Dinarska karbonatna platforma*** na jugu (kamnine Banjške planote, Trnovskega gozda, Krasa, Hrušice, Snežnika, Notranjske, južnega dela Posavskih gub, Dolenjskega krasa in Bele krajine) ter vmesni relativno globljevodni ***Slovenski bazen***, katerega kamnine najdemo danes v predgorju Julijskih Alp in v osrednjem delu Slovenije. V manjšem merilu pa je bila paleogeografska razporeditev precej bolj zapletena. Slovenska karbonatna platforma je namreč v osrednjem delu razpadla na majhne izolirane karbonatne platforme, obdane z globljimi bazeni, nekateri bloki pa so v tej fazi celo okopneli. Tam je erozija odstranila del starejših kamnin, ki so bile presedimentirane v pisane konglomerate.

Novonastali bazeni so bili globoki le nekaj sto metrov. V ladiniju se je v njih odložilo značilno zaporedje temnih skrilavih glinavcev, ki se menjavajo s peščenjaki, brečami in tufi (Psevdoziljska formacija). Sedimentacijo so spremljale intruzije vulkanskih kamnin, ki jih predstavljajo keratofir, porfirit in diabaz. S srednjetriasno magmatsko-tektonsko dejavnostjo je povezan nastanek svetovno znanega živosrebrovega rudišča v Idriji, kjer so orudene karbonske, permske, spodnje- in srednjetriasne plasti. Ladinijske plasti so orudene tudi v severnih Karavankah. Svinčevo-cinkovo rudišče v Mežici je nastalo v lagunskih in grebenskih karbonatnih kamninah

Sl. 2.4. Slovenske Alpe v veliki meri gradijo mezozojski plastnati apnenci karbonatnih platform. Velika Mojstrovka v Julijskih Alpah. *Marko Vrabec*

Fig. 2.4. Slovenian Alps are to a large part built up of bedded Mesozoic carbonate platform limestones. Velika Mojstrovka in the Julian Alps. *Marko Vrabec*

## MESOZOIC

Rocks of Mesozoic age are the most abundant rocks in Slovenia. Paleogeographically they belong to the northern margin of Adria. The Adriatic domain was bounded by the Alpine Tethys (Piemont-Liguria ocean) to the north and the west, and by the Vardar ocean to the east. The continental margin underwent two phases of extension during the Triassic and Jurassic, followed by compression which began in the Cretaceous and has been continuing up until now.

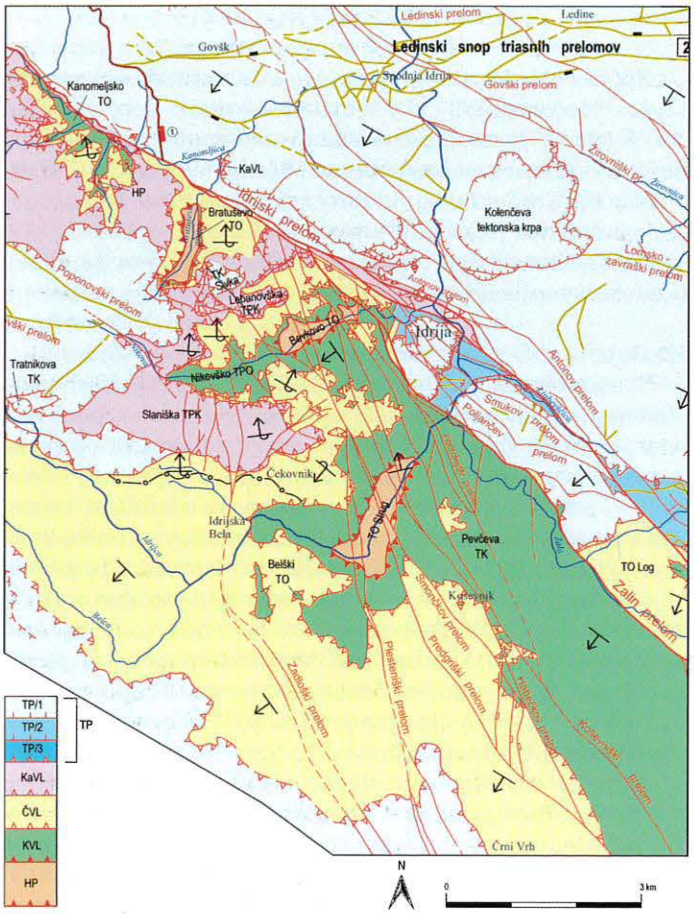
### Triassic

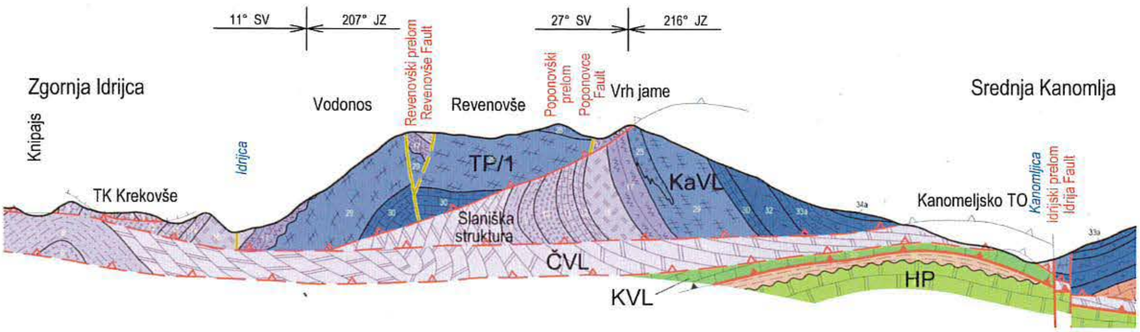
Shallow-marine sedimentation on the Slovenian Carbonate Platform, which commenced in the Late Permian, persisted into the **Early Triassic**. First the mixed siliciclastic-carbonate sediments of the Werfen Formation were deposited. These include sandstones, micaceous marls with abundant fossils, and various carbonates, including diagnostic red oolite limestones. The only exception are the reddish sandstones and mudstones of continental facies, outcroping in the present-day north-eastern Slovenia (Northern Karavanke, Pohorje and Kobansko). In the **Anisian**, the input of terrigenous material terminated, and shallow-water limestones were deposited and subsequently dolomitized. Sporadically, Anisian reef-type and algal limestones also occur.

In the **Middle Triassic**, the new Meliata Ocean started to open along the Eurasian margin. On the Slovenian Carbonate Platform, this rifting was reflected in the **Mid-Anisian to Ladinian** extensional tectonics. Extension was accompanied by volcanism, which varied in compositional character from acidic to intermediate and eventually basic. This volcanic activity implies that the rifting had also begun in the area of the Slovenian Carbonate Platform, but was soon aborted.

Middle Triassic extension fragmented the carbonate platform into separate tectonic units with a different subsidence history. Three major paleogeographic units can be recognized: the ***Julian Carbonate Platform*** in the north (comprising rocks of the present-day Southern Karavanke mountains, the Julian Alps and the Kamnik-Savinja Alps), the ***Dinaric Carbonate Platform*** in the south (comprising rocks which outcrop today in the Banjšice plateau, Trnovski gozd, Kras, Hrušica, Snežnik, Notranjska, southern Sava Folds, the karst of Dolenjska, and Bela Krajina), and the ***Slovenian Basin***, which was a deep-water domain between the two platforms (comprising rocks of the present-day foreland of the Julian Alps and central Slovenia). However, on a smaller scale more complex paleotopography can be inferred. The central part of the Slovenian Platform was morphologically differentiated into several small isolated carbonate platforms surrounded by deeper-water environments, whereas in places some tectonic blocks were elevated above sea level, contributing sediment material to conglomerates.

The majority of the newly formed basins was relatively shallow; not deeper than several hundred metres. The characteristic succession of dark shales with sandstone, breccia and tuff intercalations (the Pseudozilian Formation) was deposited during the Ladinian. The Ladinian sedimentation




Sl. 2.5. Izseka iz tektonske karte in profila na novi geološki karti idrijsko-cerkljanskega hribovja (MLAKAR & ČAR, 2009) kažeta narivno zgradbo, značilno za večji del ozemlja Slovenije. V coni Idrijskega preloma so strukturni odnosi med tektonskimi enotami še bolj zapleteni.

Legenda:
TP - Trnovski pokrov;
TP/1 - Tičenska notranja narivna gruda;
TP/2 - Idrijska notranja narivna gruda;
TP/3 - Petkovškova notranja narivna gruda;
KaVL - Kanomeljska vmesna luska;
ČVL - Čekovniška vmesna luska;
KVL - Koševniška vmesna luska;
HP - Hrušiški pokrov.

Fig. 2.5. Sections of tectonic map and of cross-section in the new geological map of the Idrija-Cerkno hills (MLAKAR & ČAR, 2009) show nappe structure, characteristic for most of the territory of Slovenia. In the Idrija fault zone, structural relations among tectonic units are even more complicated.

Explanation:
TP - Trnovo nappe;
TP/1 - Tičnica internal thrust block;
TP/2 - Idrija internal thrust block;
TP/3 - Petkovšek internal thrust block;
KaVL - Kanomlja thrust slice;
ČVL - Čekovnik thrust slice;
KVL - Koševnik thrust slice;
HP - Hrušica nappe.

Wettersteinske formacije, ki bočno prehajajo v globljevodne glinavce in laporovce Partnaške formacije.

V zgornjem ladiniju je bilo konec ekstenzije in z njo povezanega ugrezanja, kar je posledično povzročilo postopno zasipavanje bazenov in progradacijo karbonatnih platform v karniju. Progradacija ne doseže najglobljih območij bazenov, v katerih so se v **karniju** še vedno odlagali globljevodni črni glinavci in peščenjaki (amfiklinske plasti). Sočasno so se na karbonatnih platformah usedali apnenci z apnenčevimi algami, na nekaterih mestih Julijske karbonatne platforme pa so uspevali tudi kopasti koralni in spongijski grebeni.

Srednji del karnijske dobe je bil tektonsko spet aktiven, kar se je izrazilo v okopnitvi notranjega dela Dinarske karbonatne platforme in v nastanku boksitov ter rdečkastih peščenjakov, glinavcev in breč Borovniške formacije. Na severnem

was accompanied by magmatic activity, represented by keratophyre, porphirite and diabase occurrences. Middle Triassic volcanism produced the world-famous Idrija mercury deposit. Coeval lagoonal and reef-type carbonates of the Ladinian Wetterstein Formation in the Northern Karavanke contain a lead-zinc deposit.

Extension terminated in the Upper Ladinian, which resulted in the basins filling up and carbonate platform progradation in the **Carnian**. Progradation did not reach the deepest parts of the Slovenian Basin, where Carnian deep-water black shales and sandstones (the Amphiclina Formation) were deposited.

A renewal of tectonic activity in the Middle Carnian resulted in emersion of the internal part of the Dinaric Carbonate Platform, which produced bauxites, and reddish sandstones, delu Dinarske karbonatne platforme pa so se odlagali sladkovodni in brakični črni apnenci. Na Julijski karbonatni platformi se je karnijski tektonski dogodek pokazal v nastanku intraplatformnih jarkov. V jarkih so se sedimentirali apnenci z roženci, medtem ko so na platformi nastajali plastoviti apnenci, ki so večinoma dolomitizirani.

V **noriju in retiju** je bil podvodni relief že relativno izravnan. Na Julijski karbonatni platformi so nastajali dachsteinski apnenci in koralni grebeni. Istočasno so se na Dinarski karbonatni platformi odlagali plitvovodni apnenci, ki so bili pozneje večinoma spremenjeni v dolomit (glavni dolomit). Kamnine obojih formacij, ki dosežeta debelino do 1500 m, so v Sloveniji najbolj razprostranjene. Območje Slovenskega bazena je ostalo globlje; v njem najdemo ploščaste dolomite z roženci (baški dolomit).

### Jura

S koncem triasa se je začel razpad superkontinenta Pangee. Z začetkom odpiranja Atlantika se je v juri v alpskem prostoru oblikoval transferni sistem oceanskih jarkov, ki se je razvil v ozek oceanski prostor – Alpsko Tetido. Jadranska plošča se je s tem na svojem zahodnem in severnem robu ločila od Evrazije, na vzhodu pa je mejila na Vardarski ocean, ki je bil del oceanskega prostora Neotetide. Tako je naše ozemlje v juri pripadalo severnemu, pasivnemu kontinentalnemu robu Jadranske plošče. Glavni vpliv na jursko sedimentacijo v slovenskem prostoru je imela ekstenzija, povezana z odpiranjem jurske Alpske Tetide in Vardarskega oceana, ki je trajala od meje trias/jura do srednje jure. Drugače kot srednjetriasna je jurska ekstenzijska faza povzročila nastanek pravih globokovodnih bazenov in podmorskih planot, ki so

shales and breccias of the Borovnica Formation. In the northern part of the Dinaric Carbonate Platform, freshwater and brackish black limestones were deposited. On the Julian Carbonate Platform, the Middle Carnian tectonic event generated intraplatform grabens, where limestones with cherts were deposited. At the same time, bedded limestones were sedimented on the platform. Subsequently, the platform limestones were dolomitized to a large extent.

In the **Norian and Rhaetian** the underwater topography was relatively level again. On the Julian Carbonate Platform coral reefs and the Dachstein limestone were deposited. On the Dinaric Carbonate Platform, shallow water limestones were sedimented and later changed into dolomite (the Main Dolomite Formation). In the intervening Slovenian Basin, which remained deeper relative to both platforms, platy dolomite with chert (Bača dolomite) was deposited.

### Jurassic

At the end of the Triassic a major rifting episode began, resulting in the break-up of the supercontinent Pangea and opening of the Atlantic Ocean. In the Alpine domain, a system of transform basins formed which evolved in a narrow oceanic trough, the Alpine Tethys. The opening of the Alpine Tethys separated Adria from Eurasia. To the east, Adria was bounded by the Vardar Ocean, a part of the Neotethys oceanic realm. The precursor of the territory of Slovenia was located on the northern passive continental margin of the Adriatic microplate. Sedimentation was to a large degree influenced by extension associated with the opening of the Alpine Tethys and the Vardar Ocean, which lasted from the Triassic/Jurassic boundary to the Middle Jurassic. In contrast to Middle Triassic ex-

Sl. 2.6. Nariv »Slatenske plošče« nad Dolino Triglavskih jezer v Julijskih Alpah.
*Igor Košir*

Fig. 2.6. "Slatna plate" thrust above the Triglav Lakes Valley in the Julian Alps.
*Igor Košir*

obstajali vse do konca krede. Na območju današnje Slovenije jo lahko razdelimo na dve glavni fazi intenzivnega tektonskega pogrezanja.

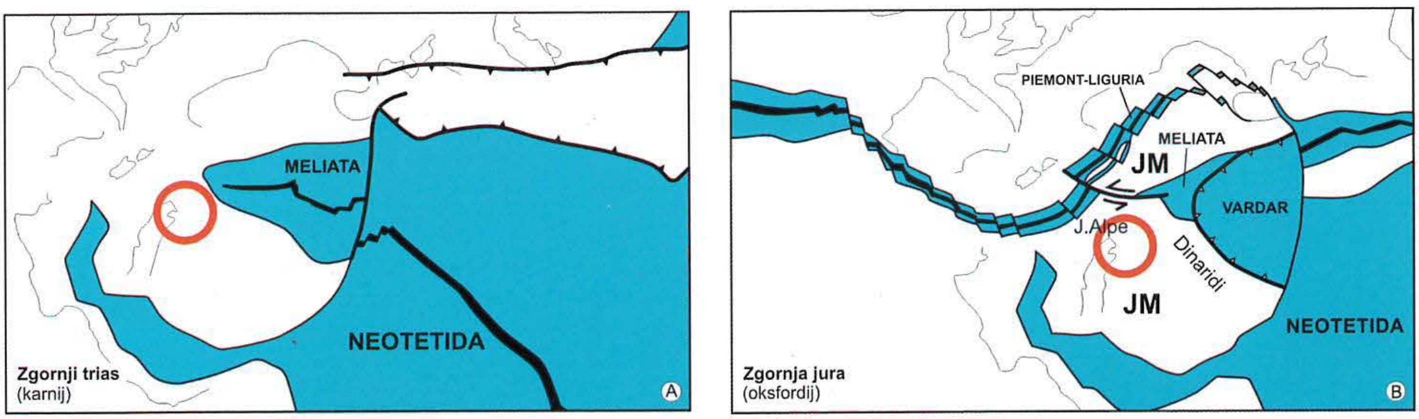
Prva faza pogrezanja na meji trias/jura je izraz začetka riftinga pred odpiranjem Alpske Tetide in »Vardarja«. Povzročila je poglobitev Slovenskega bazena, v katerem v tem času prevladuje sedimentacija karbonatnih gravitacijskih tokov (Krikovska formacija). V tem času se nekoliko poveča globina vode tudi nad Julijsko in Dinarsko karbonatno platformo. Na obeh platformah je bila odložena več sto metrov debela skladovnica spodnjejurskih plitvovodnih oolitnih apnencev. Posebnost predstavljajo srednje spodnjejurski temnosivi apnenci z velikimi školjkami iz skupine litiotid, ki so značilni za severne dele Dinarske karbonatne platforme. V toarciju so se v času globalnega anoksičnega dogodka v Slovenskem bazenu odlagali glinavci in laporovci Perblanske formacije.

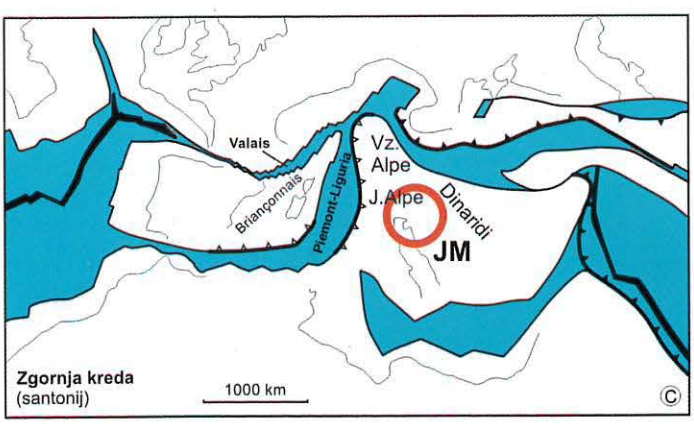
Druga faza pogrezanja je bajocijske starosti in jo pojasnjujemo kot termalno pogojeno ugrezanje litosfere, ki je sledilo odpiranju oceanov Alpske Tetide in »Vardarja«. Ta faza je povzročila dodatno poglabljanje Slovenskega bazena, v katerem so posledično začeli nastajati radiolarijski roženci s posameznimi vmesnimi plastmi apnenčevih turbiditov (Tolminska formacija). Julijska karbonatna platforma se v tem času pogrezne in postane podmorski plato, imenovan Julijski plato, na katerem so bili odloženi globljevodni rdečkasti gomoljasti in krinoidni apnenci tipa *ammonitico rosso* (Prehodavci formacija), ki vsebujejo amonite, ponekod pa tudi manganove gomolje in rudo. Topografska razlika med Slovenskim bazenom

tension, the Jurassic extensional episode produced extensive deep-water basins and submarine plateaux, which existed up to the end of the Mesozoic. The Jurassic extensional episode consists of two major subsidence phases.

The first subsidence phase at the Triassic/Jurassic transition, which was related to initial rifting of the Alpine Tethys and Vardar, caused deepening of the Slovenian Basin, in which sedimentation of carbonate gravity flows (the Krikov Formation) prevailed. Water depth was also somewhat increased above the Julian and Dinaric Carbonate Platforms. Several hundred metres of Lower Jurassic shallow-water oolitic limestones were deposited on both platforms. Conspicuous Middle Lower Jurassic dark grey limestones with thick shells of *Lithiotis* bivalves are typical for the northern parts of the Dinaric Carbonate Platform. During the Toarcian oceanic anoxic event, the shales and marls of the Perbla Formation were deposited in the Slovenian Basin.

In the Bajocian thermal subsidence followed the first subsidence phase. Further deepening of the Slovenian Basin favoured the deposition of radiolarian cherts intercalated with calcareous turbidites (the Tolmin Formation). The Julian Carbonate Platform subsided to become a pelagic plateau named the Julian High, where a succession of nodular *ammonitico rosso*-type limestones of the Prehodavci Formation was deposited. The Prehodavci Formation contains abundant ammonites and manganese nodules. At the end of the Jurassic, the sedimentation of white thin-bedded pelagic Biancone Limestones with cherts was taking place both in the Slovenian




Sl. 2.7. Mezozojska tektonika plošč in paleogeografija južnoevropskega prostora (poenostavljeno po: Schmid et al., 2004). Krog označuje približno lokacijo ozemlja današnje Slovenije. JM – Jadranska (Apulijska) mikroplošča; J. Alpe – Južne Alpe; Vz. Alpe – Vzhodne Alpe.

Fig. 2.7. Mesozoic plate tectonics and paleogeography in the south-European domain (simplified from: Schmid et al., 2004). A – Late Triassic (Carnian); B – Late Jurassic (Oxfordian); C – Late Cretaceous (Santonian). Circle marks the approximate position of present-day territory of Slovenia. JM – Adriatic (Apulian) microplate; J. Alpe – Southern Alps; Vz. Alpe – Eastern Alps; Dinaridi – Dinarides; Neotetida – Neotethys.

in Julijskim platojem je ob koncu jure že delno izenačena, kar se kaže v enotni sedimentaciji pelagičnih belih ploščastih apnencev z roženci (*biancone* apnenci) v obeh globljevodnih okoljih.

Druga faza pogrezanja ni bistveno vplivala na sedimentacijo na Dinarski karbonatni platformi, kjer se v srednji juri nadaljuje plitvovodna sedimentacija oolitnih in drobnozrnatih apnencev. V zgornji juri (spodnjem malmu) pa je na severnem robu Dinarske karbonatne platforme nastal velik koralni greben bariernega tipa, katerega ostanki potekajo bolj ali manj sklenjeno z območja današnje severne Italije prek Banjšic, Trnovskega gozda in Hrušice na Dolenjsko in v Belo krajino ter naprej na Hrvaško. Grebenski apnenci, ki dosežejo do 500 m debeline, vsebujejo veliko koral, spongij in hetetid. Južnejši del karbonatne platforme se je za krajši čas dvignil nad morsko gladino. Na njem je nastal boksit, ki ga najdemo na Nanosu, Hrušici, Logaški planoti in pri Žužemberku.

Že v zgornji juri se je na vzhodni kontinentalni rob Jadranske plošče v poteku obdukcije narinila oceanska skorja Vardarskega oceana. Narinjeni ofioliti in spremljajoče kamninske združbe gradijo današnjo enoto Notranjih Dinaridov, ki pa ne sega na območje Slovenije. Ta kompresijski dogodek na bolj internih območjih Jadranske plošče, ki jim pripadajo karbonatne platforme slovenskega ozemlja, je bil blago izražen in se je kazal v obliki lokalno omejenih poplitvitev in poglobitev sedimentacijskega prostora.

### Kreda

V spodnji kredi je ob subdukciji in zaprtju oceana Meliata v vzhodnem delu Alpskega orogena prišlo do orogeneze in obsežnega narivanja avstroalpinskih pokrovov proti severozahodu do zahodu, ki ga je spremljal različno močan metamorfizem. Avstroalpinski pokrovi gradijo ozemlje Strojne, Kozjaka in Pohorja v severovzhodni Sloveniji. Spodnjo strukturno enoto gradijo gnajsi, blestniki, amfiboliti, eklogiti in granatovi peridotiti, ki so verjetno nastali iz kamnin distalnega kontinentalnega robu Jadranske plošče. Te kamnine so bile v kredni orogenezi subducirane v velike globine, kar dokazujejo pojavi ultravisokotlačnega metamorfizma na Pohorju, nato pa so bile v zgornji kredi z mehanizmom tektonske ekstrakcije ponovno vzdignjene bliže površju. Čez to enoto je narinjen pokrov iz šibkometamorfoziranih do nemetamorfnih kamnin kontinentalnega robu Jadranske plošče, ki ga sestavljajo skrilavci Štalenskogorske serije in permotriasne sedimentne kamnine. Spodnjekredni orogenezi je sledila ekstenzijska faza v zgornji kredi, ki jo tolmačijo kot ekstenzijski kolaps avstroalpinskega orogena. Narivne ploskve so se reaktivirale kot položni normalni prelomi, v hitro ugrezajočih se ekstenzijskih bazenih in jarkih pa so se usedali kontinentalni do globljevodni morski sedimenti Gosavske formacije. Pri nas najdemo erozijske krpe gosavskih plasti na severnih in južnih obronkih Pohorja.

Na Dinarski karbonatni platformi se je iz jure nadaljevala plitvovodna sedimentacija, ki je trajala še večji del krede. V spodnji kredi so se v razgibanem okolju karbonatne platforme odlagali plitvovodni apnenci Brske in Povirske formacije, sedimentacija pa je bila občasno prekinjena z emerzijskimi

Basin and on the Julian High. This indicates that the sea-bottom topography became predominantly levelled by the end of Jurassic.

The thermal subsidence phase did not have a significant influence on sedimentation on the Dinaric Carbonate Platform. Deposition of shallow-water oolitic and limestones continued into the Middle Jurassic. In the Late Jurassic (Upper Oxfordian and Kimmeridgian) a barrier reef formed along the northern margin of the platform. The remains of this reef can be traced today from Italy accross the Banjšice, Trnovski gozd, Dolenjska and Bela Krajina into Croatia with reef limestones attaining a thickness of up to 500 m. A short-term emersion of the southern part of the Dinaric Carbonate Platform produced bauxite deposits, found today on the Nanos, Hrušica, Logatec plain and at Žužemberk.

In the Late Jurassic the oceanic crust of the Vardar Ocean was obducted onto the eastern continental margin of Adria. Obducted ophiolites and their associated rocks build the tectonic unit of the Internal Dinarides, which does not extend into Slovenia. In the more internal parts of Adria, to which the Slovenian carbonate platforms belong, this compressional event was reflected by localized uplift and subsidence.

### Cretaceous

In the Early Cretaceous, the subduction and closure of the Meliata Ocean led to orogeny in the eastern part of the Alpine orogen. Extensive NW- to N-directed thrusting of the Austroalpine nappes was associated with metamorphism of various grades. Austroalpine nappes build up the territory of Strojna, Kozjak and Pohorje in north-eastern Slovenia. The lower structural unit consists of gneisses, micashists, amphibolites, eclogite and garnet peridotite, which probably originate from the distal contintental margin of Adria. During the Cretaceous orogeny, these rocks were buried to great depths, evidenced by the occurrence of ultra-high pressure metamorphism in Pohorje. In the Late Cretaceous these rocks were exhumed back close to the surface. The weakly- to non-metamorphosed nappe consisting of Magdalensberg Series schists and Permotriassic sedimentary rocks, belonging to the Adriatic continental margin, was thrust over the structurally lower Austroalpine unit.

Early Cretaceous compression was followed by the Late Cretaceous phase of extension, which is interpreted as an orogenic collapse of the Austroalpine orogen. In the rapidly subsiding extensional basins and grabens, a successon of continental to deep-water sediments of the Gosau Formation was deposited. Erosional patches of the Gosau beds are present in the Pohorje area.

Shallow water sedimentation persisted on the Dinaric Carbonate Platform throughout most of the Cretaceous. In the Early Cretaceous, shallow-water limestones of the Brje Formation and the Povir Formation were deposited. Sedimentation was interrupted by occasional emersions. In the the Late Cretaceous, at the Cenomanian-Turonian boundary, the Dinaric Carbonate Platform was drowned due to the eustatic sea level rise. This event is marked by the deposition of pelagical limestones of the Repen Formation. Shallow-water sedimentation fazami. Plitvovodna sedimentacija je bila v zgornji kredi, na meji cenomanij-turonij, prekinjena. Zaradi evstatičnega dviga morske gladine in sinsedimentne tektonike se je večji del Dinarske karbonatne platforme potopil in začeli so nastajati pelagični apnenci Repenske formacije. Plitvovodna sedimentacija se je ponovno vzpostavila v zgornjem turoniju, s sedimentacijo plitvovodnih debeloplastnatih apnencev s številnimi rudisti in velikimi bentoškimi foraminiferami (Sežanska in Lipiška formacija). Litološka posebnost na Krasu so tudi črni ploščasti in laminirani komenski in tomajski apnenci, ki se pojavljajo znotraj vseh zgornjekrednih formacij in so znani zaradi fosilnih rib.

V globljevodnih okoljih našega ozemlja se je jursko-kredna sedimentacija pelagičnih apnencev Biancone formacije prekinila s sedimentacijo spodnjekrednih klastičnih flišoidnih kamnin. Te so valanginijsko-hauterivijske in aptijsko-albijske starosti, ki z erozijsko diskordanco nalegajo na starejše kredne in jurske kamnine. Odlaganje fliša je povezano s spodnjekredno avstroalpinsko orogenezo ob severnem obrobju Jadranske plošče. Sedimentacija globljevodnih kamnin se nadaljuje do cenomanija, ko začnejo nastajati laporasti apnenci z globotrunkanami.

V zgornji kredi je ob severovzhodnem robu Jadranske plošče prišlo do kolizije s kontinentalno litosfero, ki bi lahko pripadala današnji mega-enoti Tisa ali kakemu drugemu fragmentu kontinentalne litosfere v oceanskem prostoru med Jadransko in Evrazijsko ploščo. Kolizija se je pri nas najprej izrazila z začetkom sedimentacije karbonatnih turbiditov (Volčanska formacija) v Slovenskem bazenu, temu pa je v najmlajši kredi sledil mešan karbonatni in siliciklastični fliš, ki je zasul Slovenski bazen. Kolizijski narivni sistem pretežno položnih narivov je napredoval v smeri od severovzhoda proti jugozahodu. Sočasno se je v to smer premikala tudi fleksurna predgorna udorina, v kateri so se odlagale flišne plasti. Še pred koncem krede so te dosegle in prekrile severni rob Dinarske karbonatne platforme. Ni še čisto jasno, ali to narivanje smemo uvrstiti že v dinarsko narivno fazo, saj se je narivanje v južneje ležečih delih Zunanjih Dinaridov Hrvaške in Bosne začelo šele v eocenu.

S pomikanjem predgorne udorine proti jugozahodu postajajo sedimenti v napredujočih bazenih vse mlajši. Hkrati so zaradi fleksurne izbočitve litosfere na periferni predizboklini fleksurnega bazena pogledale kamnine Dinarske karbonatne platforme nad vodno gladino. Nastala je kraška erozijska diskordanca, na kateri so se ponekod odložili boksiti ali breče, v katerih so pri Kozini našli ostanke dinozavrov. Sledove te diskordance najdemo danes v delu jugozahodne Slovenije in v Istri. Pri nadaljnjem napredovanju narivanja se je periferna predizboklina začela polagoma ponovno pogrezati. Na erozijski diskordanci se je odložil apnenec Liburnijske formacije, ki je nastajal v sladkovodnem, brakičnem in morskem okolju in vsebuje pri Vremskem Britofu in Lipici plasti črnega premoga močvirskega izvora. Odlaganje kamnin Liburnijske formacije se je nadaljevalo tudi v paleogenu.

was re-established in the Upper Turonian, when thick-beds of limestones with rudists and bentic foraminifera of the Sežana and the Lipica Formation were deposited. Thin sequences of black platy laminated limestones, containing fish fauna (the Komen limestones and the Tomaj limestones) are contained in all Upper Cretaceous formations of the Dinaric Carbonate Platform.

In the area north of the Dinaric Carbonate Platform, the Austroalpine orogeny was reflected by the deposition of Early Cretaceous (Valanginian-Hauterivian and Albian-Aptian) clastic flischoid beds, which unconformably overlie the Jurassic-Cretaceous pelagical limestones of the Biancone Formation. Deep-water sedimentation continued into the Cenomanian, when marly limestones with *Globotruncana* were deposited.

In the Late Cretaceous, the north-eastern margin of Adria collided with the continental lithosphere, which could belong to the Tisza megaunit or some other fragment of the continental lithosphere from the oceanic domain between Adria

Sl. 2.8. Manjši reverzni prelom z obprelomnimi gubami seka plasti krednega volčanskega apnenca. Prelom je verjetno nastal pri narivanju Južnih Alp v miocenu. Koseška korita pri Drežnici. *Marko Vrabec*

Fig. 2.8. A small reverse fault with drag folds cutting through beds of Cretaceous Volče limestone. The origin of the fault is presumably related to the South-Alpine thrusting episode in Miocene. Koseška korita near Drežnica, Julian Alps. *Marko Vrabec*

## KENOZOIK

### Paleogen

Na območju slovenskih Zunanjih Dinaridov se je iz zgornje krede v **paleocen** zvezno nadaljevala flišna sedimentacija v napredujočem fleksurnem predgornem bazenu. Istočasno se je vzdolž jugozahodnega roba flišnega bazena – na ***Paleogenski jadranski karbonatni platformi*** – nadaljevala karbonatna sedimentacija. Z nadaljnjim tonjenjem prvotne predizbokline so bile kontinentalno-morske plasti Liburnijske formacije prekrite s plastmi foraminifernih apnencev Trsteljske formacije, ki so tvorile plitve periferne karbonatne platforme fleksurnega bazena. Karbonatna sedimentacija se konča z alveolinsko-numulitnimi apnenci spodnje- in srednje**eocenske** starosti. V končni fazi poglabljanja, ko je območje prvotne predizbokline prešlo v osrednji del fleksurnega bazena, prekrije karbonatno platformo tanko zaporedje prehodnih karbonatno-klastičnih plasti, temu pa sledi globokovodni klastični fliš. Starost fliša se sistematično spreminja, kar kaže na napredovanje narivanja in pomikanje sinorogenega bazena proti jugu in jugozahodu: v spodnjem Posočju je fliš zgornjekredni, v Anhovem, na Banjšicah in na Kočevskem je paleocenski, v Goriških Brdih, Vipavski dolini in Pivški kotlini ter pri Ilirski Bistrici paleocenski in spodnjeeocenski, južneje proti Istri pa spodnje- do zgornjeeocenski.

V zadnji fazi razvoja so flišno sedimentacijo prekinili narivi, ki so deformirali in delno prekrili flišne bazene. Domnevamo, da je narivanje trajalo do oligocena. Rekonstruirana dolžina dinarskega narivanja na ozemlju jugozahodne Slovenije je ocenjena na vsaj 30 km, pri čemer pa je treba upoštevati, da so zaradi poznejših zmičnih premikov in južnoalpskega narivanja dinarske narivne strukture v severovzhodni polovici Slovenije slabo poznane, tako da je bila skupna deformacija na ozemlju Slovenije najverjetneje še večja.

V zaledju Dinarskega fleksurnega flišnega bazena v današnji osrednji in severni Sloveniji iz začetka paleogena nimamo ohranjenih kamnin. Najstarejše sedimentne kamnine so eocenske starosti in jih najdemo le kot posamezne ostanke v Karavankah, jugozahodno od Pohorja in na Boču.

Z začetkom **oligocena** so kolizijski procesi in nastajanje gorskih verig Alp, Dinaridov in Karpatov na ozemlju srednje in vzhodne Evrope izolirali od Atlantika in Tetide plitev morski prostor Paratetide, ki je pri nas obstajala do pliocena. Že ob koncu eocena in v spodnjem oligocenu se je na našem ozemlju začela sedimentacija v bazenu, katerega kamnine najdemo danes v osrednji in severni Sloveniji, v osrednji Madžarski in na Slovaškem. Bazen pojasnjujejo kot fleksurni zaločni bazen subdukcijsko-kolizijske cone ob severnem robu Alp in Karpatov. Sedimentacija na našem ozemlju se je večinoma začela na zakraselem paleoreliefu z lokalnimi pojavi boksita. Bazalne plasti so pretežno kontinentalnega do brakičnega značaja s konglomerati in premogom, ki je v Zasavju nakopičen v ekonomskih količinah. Navzgor prehajajo v plitvovodne apnence in končno celo v batialne drobnozrnate klastične sedimentne kamnine, kar kaže na hitro poglabljanje sedimentacijskega prostora. Kamnine tega zaporedja

and Eurasia. In the Slovenian Basin, the first manifestation of collision was the deposition of carbonate turbidites of the Volče Formation, followed by the mixed siliciclastic-carbonate flysch, which filled the Slovenian Basin in the uppermost Cretaceous. Flysch sediments were deposited in a flexural foreland basin in front of the low-angle thrusts propagating top-to-the-southwest. By the end of the Cretaceous, the flysch sediments had reached and eventually covered the northern margin of the Dinaric Carbonate Platform.

In the forebulge of the flexural basin the rocks of the Dinaric Carbonate Platform were subaerially exposed and karstified with bauxites and breccias deposited locally. The breccia outcropping near Kozina contains fragmentary dinosaur remains. With the further advance of the thrust system and gradual subsidence of the forebulge, the shallow-water limestones of the Liburnian Formation were deposited onto the karstic unconformity. The limestones of the Liburnian Formation are of a freshwater, brackish and marine character. In Vremski Britof and Lipica they contain thin layers of black coal. Sedimentation of the Liburnian Formation continued into the Paleogene.

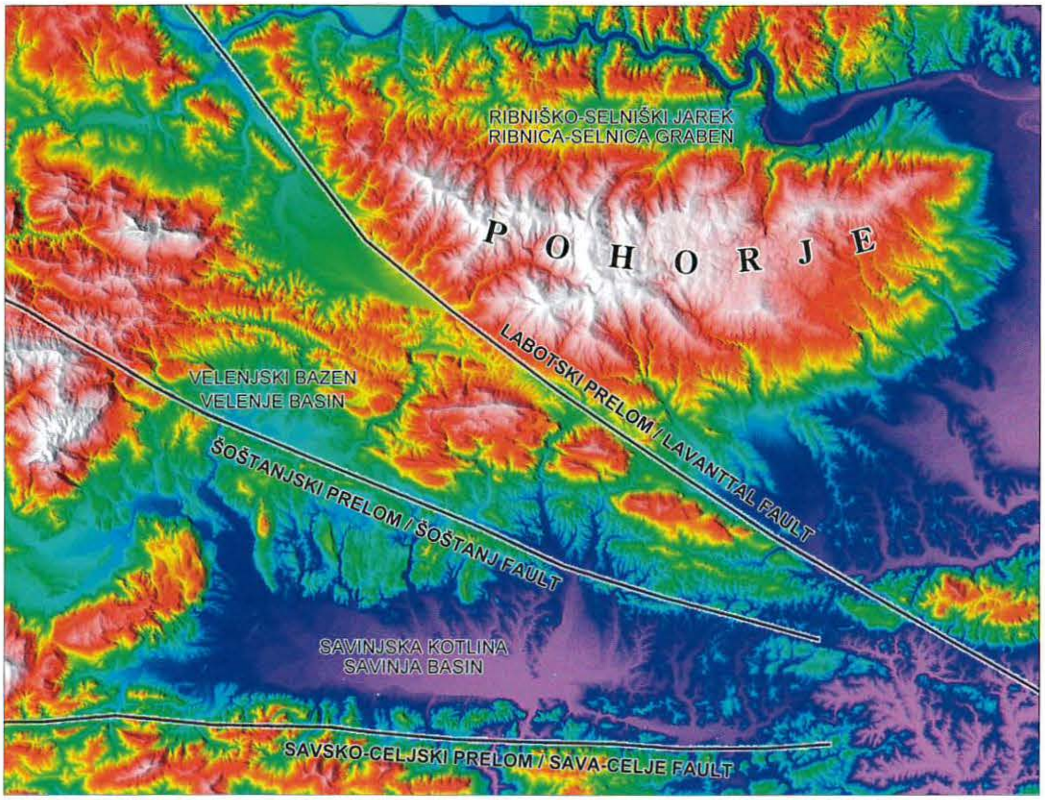
## CENOZOIC

### Paleogene

In the Slovenian Dinarides, sedimentation of flysch in the advancing foreland basin continued from the Late Cretaceous into the **Paleocene**, while along the south-west boundary of the flysch basin, carbonate sedimentation persisted on the ***Paleogene Adriatic Carbonate Platform***. The beds of the Liburnija Formation were covered by foraminiferal limestones of the Trstelj Formation, which formed shallow periphera

Sl. 2.9. Struktura dupleksa v eocenskih flišnih plasteh v Simonovem zalivu pri Izoli. *Marko Vrabec*

Fig. 2.9. Duplex structure in Eocene flysch beds in Simonov zaliv near Izola. *Marko Vrabec*




Sl. 2.10. Topografski odraz Šoštanjskega, Labotskega in Savsko-Celjskega preloma na njihovem sečišču v Severovzhodnem delu Slovenije. *Marko Vrabec*

Fig. 2.10. Topographic expression of the Šoštanj, Lavanttal and Sava-Celje faults at their junction in north-eastern Slovenia. *Marko Vrabec*

najdemo danes pri Radovljici in Škofji Loki, v predkvartarni podlagi Savske kotline, v Posavskih gubah, v zgornji Savinjski dolini in Celjski kotlini.

Po koncu subdukcije Alpske Tetide je prišlo v paleogenu do kontinentalne kolizije Jadranske in Evrazijske plošče. Konvergenca med ploščama se je v začetni fazi kolizije absorbirala predvsem z narivanjem in z vertikalnimi premiki delov Alpskega orogena ob sistemu strmih litosferskih prelomov - Periadriatskem prelomnem sistemu. V vzhodnem delu orogena je pritisk Jadranske plošče proti severu v oligocenu povzročil bočno iztiskanje (ekstruzijo) ozemlja Vzhodnih Alp proti vzhodu. Iztisnjeni blok je imel klinasto obliko, njegova južna meja pa je bil Periadriatski prelomni sistem, ki je imel v tej fazi desnozmičen značaj. Premiki so razdelili in razmaknili paleogenski fleksurni bazen na južno slovensko in severno madžarsko polovico.

Odlom subducirane oceanske plošče in z njim povezano delno taljenje skorje sta v Alpah povzročila nastanek oligocenskega periadriatskega magmatizma, ki je prostorsko vezan na območje Periadriatskega prelomnega sistema, vzdolž katerega je magma prodirala proti površju. V tej fazi magmatizma je nastalo podolgovato tonalitno telo pri Črni na Koroškem. S periadriatskim magmatizmom so povezani tudi pojavi andezitnega vulkanizma na območju Smrekovca, njegove sledove pa najdemo tudi pri Radovljici, Celju in Rogaški Slatini.

**Neogen**

Astenosferski vlek subducirane evropske litosfere pod nastajajočim orogenom Karpatov je na prehodu iz spodnjega v srednji **miocen** povzročil zelo močno raztezanje in hitro

carbonate platforms of the flexural foreland basin. Carbonate sedimentation ended with deposition of Lower- to Mid-**Eocene** limestones containing *Alveolina* and *Nummulites* foraminifera. In the final stage of drowning, the carbonate platform was first covered by a thin succession of transitional carbonate-siliciclastic beds, which were followed by thousands of metres of deep-water clastic flysch sediments. The systematic south-westward younging of flysch deposits reflects the propagation of thrusting and its associated migration of foreland flexure towards the south-west. The oldest flysch rocks, found in lower Posočje, are of Late Cretaceous age, whereas the youngest flysch deposits outcropping in Istria are of Early to Late Eocene age. In the final stage of evolution the sedimentation of flysch was terminated by thrusts, which deformed and partially overthrusted the flysch basins. The thrusting presumably lasted until the Oligocene. The distance of thrusting was reconstructed to have been at least 30 km.

No Early Paleogene rocks are known from the hinterland of the Dinaric flexural basin in present-day central and northern Slovenia. The oldest known Paleogene sedimentary rocks are of Eocene age and were found only as isolated remains in the Karavanke, Boč, and south-west of Pohorje.

At the beginning of the **Oligocene**, the rising mountain chains of the Alps, Dinarides and Carpathians isolated the shallow marine domain of the Paratethys sea, which spanned across central and eastern Europe. Even at the end of the Eocene and in the Lower Oligocene, deposition began in the basin whose sediments are today found in northern and central Slovenia, central Hungary and in Slovakia. This basin is interpreted as a retro-arc flexural basin of the subduction-collision

Sl. 2.11. Duktilne strižne cone v miocenskem pohorskem granodioritu v kamnolom Cezlak. Deformacije so povezane z ekstenzijsko ekshumacijo plutona v tenziji s smerjo vzhod-zahod med ugrezanjem Panonskega bazena. *Marko Vrabec*

Fig. 2.11. Ductile shear zones in Miocene granodiorite of Pohorje in Cezlak quarry. Deformation is related to extensional exhumation of the granodiorite pluton in E-W oriented tension, accompanied with the Pannonian Basin subsidence. *Marko Vrabec*

ugrezanje litosfere v intraorogenskem prostoru med Karpati, Dinaridi in Vzhodnimi Alpami. Nastalo je obsežno, strukturno kompleksno ekstenzijsko območje, ki ga imenujemo Panonski bazen, v katerem se je odložilo več kilometrov debelo zaporedje pretežno klastičnih sedimentnih kamnin. Miocenske kamnine Panonskega bazenskega sistema pokrivajo obsežna področja severovzhodne Slovenije v Prekmurju, Halozah, Slovenskih goricah, vzhodno in zahodno od Maribora ter v širši okolici Slovenj Gradca. Preko Posavskih gub segajo vse do osrednje Slovenije, vendar pa so bile v tem predelu pozneje nagubane in deloma erodirane.

Pri ugrezanju Panonskega bazena so bile narivne ploskve krednega Vzhodnoalpskega orogena reaktivirane kot položni normalni prelomi, kar lahko opazujemo na območju Pohorja in Kozjaka. Ekstenzija je povzročila hitro ekshumacijo metamorfnih kamnin Pohorja proti površju, z njo pa je najverjetneje vzročno povezana tudi miocenska intruzija granodioritnega telesa v Pohorski metamorfni kompleks, ki jo je spremljal dacitni vulkanizem. Na območju vzhodno in jugovzhodno od Pohorja je bilo ugrezanje bazenov in tektonskih jarkov zelo hitro, zapolnjevali pa so jih predvsem sedimenti gravitacijskih tokov, pomešani z vulkaniti. Zahodneje prevladujejo kontinentalni in plitvovodni morski klastični sedimenti, peščenjaki, konglomerati in laporovci, ki jih danes najdemo razgaljene v Posavskih gubah. Sovpadanje tektonske aktivnosti in globalnega upada morske gladine je na začetku srednjega miocena povzročilo okopnitev in nastanek erozijske diskordance.

V srednjem miocenu je prišlo do druge faze hitrega pogrezanja. Na začetku prevladuje sedimentacija v okolju plitve karbonatne platforme s številnimi ostanki rdečih alg, briozo-

zone which runs along the northern margin of the Alps and Carpathians. In Slovenia, the basal beds of continental to brackish character, predominately conglomerates with some coal intercalations, were deposited onto a karstic unconformity with localized bauxite occurrences. Upwards the sedimentation gradually changed to shallow-marine limestones and finally to batial fine-grained clastics, which indicates rapid subsidence of the basin. The strata belonging to this succession are found at Radovljica and Škofja Loka, in the pre-Quaternary basement of the Sava depression, Sava Folds area, upper Savinja valley and in the Celje depression.

The subduction of Alpine Tethys ended in the Paleogene, which resulted in the continental collision of Adria and Eurasia. In the eastern part of the Alpine orogen, post-collisional convergence was to a large extent absorbed by eastward extrusion of the Eastern Alps domain. The extruding wedge-shaped block was bound to the south by the Periadriatic fault system. A major dextral slip on the Periadriatic fault dismembered the Paleogene flexural basin into the southern Slovenian part and the northern Hungarian part.

The slab breakoff and partial melting of the subducted slab produced Periadriatic magmatism of Oligocene age. Peraidriatic magmatism was spatially associated with the Periadriatic fault system, which chanelled the rising magma. In Slovenia, the products of Periadriatic magmatism are the elongated Eisenkappel tonalite body, of which the eastern part outcrops around Črna na Koroškem, and the Smrekovec andesite volcanism, remnants of which are found in the upper Savinja valley, and near Radovljica, Celje and Rogaška Slatina.

**Neogene**

At the transition from Early to Middle **Miocene**, the slab retreat in the Carpathian subduction zone had caused major lithospheric extension and subsidence in the intra-orogenic domain between the Carpathians, Dinarides and Eastern Alps. In the resulting extensive, structurally complex Pannonian Basin, a several kilometre thick succession of predominately clastic sediments was deposited. Miocene sedimentary rocks of the Pannonian Basin cover large areas of north-eastern Slovenia in Prekmurje, Haloze, Slovenske gorice, eastward and westward of Maribor, and near Slovenj Gradec. Accross the Sava Folds area, the Pannonian Basin sediments reach westwards all the way to central Slovenia.

During the extension, thrust planes of the Cretaceous Austroalpine orogen were reactivated as low-angle normal faults. This reactivation was observed in the Pohorje and Kozjak mountains. Extension rapidly exhumed the metamorphic rocks of Pohorje to the surface. The intrusion of the Miocene granodiorite body into the Pohorje metamorphic complex and its related dacitic volcanism is also believed to be extension-related. In the area east and south-east of Pohorje, the subsidence of grabens and basins was very rapid. The basins were predominately filled with gravity flows mixed with volcanoclastic material. West of Pohorje, continental and shallow-marine clastic sediments prevailed. Sandstones, conglomerates and marls belonging to this succession are found in the Sava Folds region. At the beginning of the Middle Miocene, the combined

Sl. 2.12. Presek prelomne cone regionalnega desnozmičnega Raškega preloma v avtocestnem useku pri Senožečah. Ta prelom s smerjo severozahod-jugovzhod je še danes seizmično aktiven. Dobro je vidna kataklastično zdrobljena notranja prelomna cona s spremljajočo porušeno cono na levi. *Marko Vrabec*

Fig. 2.12. A section accross the regional dextral strike-slip Raša fault, exposed in a highway roadcut near Senožeče. This NW-SE oriented fault exhibits seismic activity. Note the cataclastically deformed core zone of the fault accompanied by fractured zone on the right side of the picture. *Marko Vrabec*

jev in koral. Z nadaljnjim pogrezanjem so se v globoki vodi čeznje odložili muljevci in ponekod sedimenti turbiditnih tokov. Na koncu srednjega miocena se je globalni nivo morske gladine spet začel zniževati. V močno poplitvenem sedimentacijskem okolju, ki je imelo mešan sladkovodni, brakični in morski značaj, so bili odloženi peski, prodi, gline in laporji. Na območju večjega dela Posavskih gub so to najmlajši znani miocenski sedimenti. Zaradi globalnega padca nivoja morske gladine in verjetno tudi tektonske aktivnosti so bile kamnine nato okopnjene in jih prekriva erozijska diskordanca.

Z začetkom zgornjega miocena se je začela še zadnja faza ugrezanja. V vzhodni Sloveniji in južnih Posavskih gubah se je odložilo debelo zaporedje pretežno klastičnih sedimentov, sprva morskih in večinoma turbiditnega značaja, proti koncu miocena pa so sedimentacijski prostor zasule rečne delte. S tem se je na našem ozemlju končala sedimentacija v Panonskem bazenskem sistemu.

Desnozmični premiki ob Periadriatskem prelomnem sistemu so se v manjši meri nadaljevali tudi v miocenu in pliocenu. Skupni desni premik vzdolž slovenskega dela prelom-

effect of tectonic activity and eustatic sea level fall resulted in emersion of the territory and the formation of erosional unconformity.

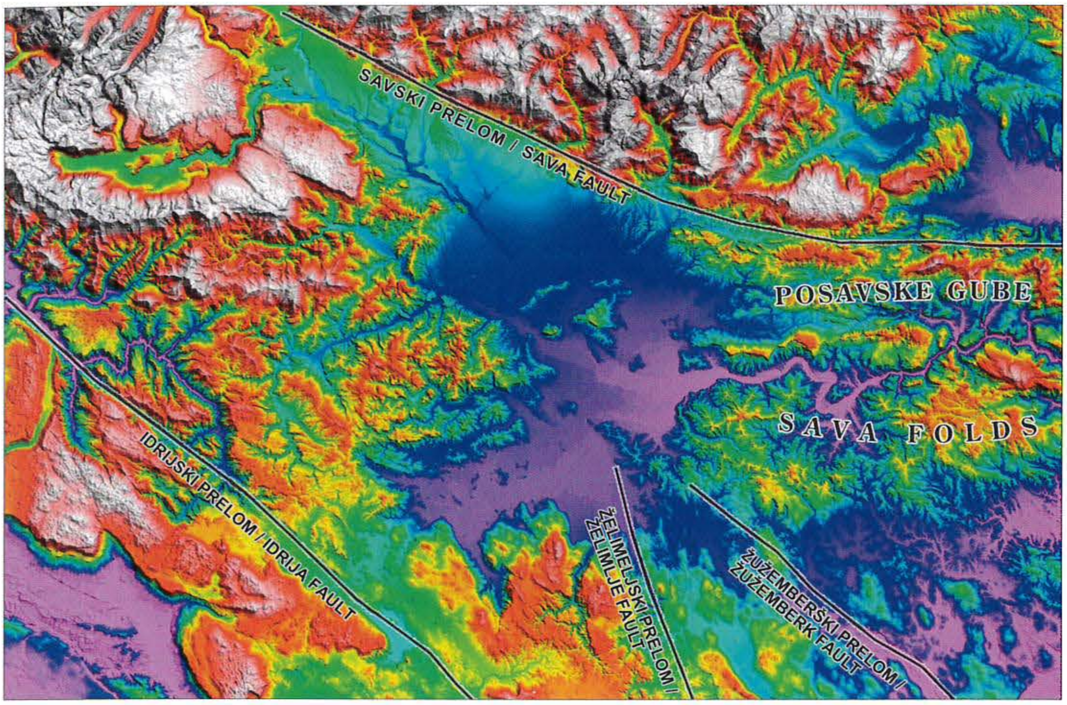
The second phase of rapid subsidence began in the Middle Miocene. Initial carbonate sedimentation on a shallow carbonate platform with abundant remains of red algae, bryozoans and corals, was followed by deep-water mudstones and occasional turbidites. By the end of the Middle Miocene, the next eustatic sea level fall changed the depositional environment sedimentation back to shalow marine, brackish and continental, with sands, gravels, clays and marls. In most of the Sava Folds region, these are the youngest known sediments. The succession is terminated by erosional unconformity.

At the beginning of the Late Miocene the final phase of subsidence had started. In eastern Slovenia and in the southern part of the Sava Folds region a thick succession of predominately clastic sediments was deposited. The lower parts of the succession are of a marine, mostly turbiditic character. They are covered by deltaic deposits that filled up the basins and have marked the end of deposition in the Slovenian part of the Pannonian Basin system.

Dextral motion on the faults of the Periadriatic fault system continued into Miocene and Pliocene epochs. The total dextral displacement along the Slovenian part of the fault system is estimated to be 100 km. Additionally, the area north of the fault was stretched during the extrusion and the Pannonian Basin extension, resulting in about 300 km of separation of the pre-Oligocene units north and south of the Periadriatic fault system. Consequently, the pre-extrusional geometry of northern Slovenia, including the hinterland of the Dinaric thrust system, is very difficult to reconstruct, particularly because the displaced northern part was covered by a thick blanket of Miocene sediments in the Hungarian part of the Pannonian Basin.

The Neogene shortening in the Adria-Eurasia collision zone produced top-to-the south thrusting of the Alps south of the Periadriatic fault system, known as the South-Alpine thrusting episode. Thrusting began in the Middle Miocene and mostly ended by the Pliocene, but appears to continue to be active in the Julian Alps and their foreland. In Slovenia, the area of the Julian Alps and the Kamnik-Savinja Alps belongs to the South-Alpine thrust system. South-Alpine thrusts overrode and deformed the older Dinaric thrust structures, which was documented in the Blegoš area.

At the transition from the Miocene to the **Pliocene**, the final closure of the oceanic embayment in the Carpathians stopped the eastward extrusion of the Eastern Alps, causing a major re-organisation of the tectonic regime in the region. Paleomagnetic data suggest that the Adriatic microplate started rotating in the CCW sense at about the same time. The Adria push caused the onset of inversion in the Pannonian Basin system. In the Sava Folds region and in eastern Slovenia a reverse reactivation of former normal faults uplifted blocks and horsts of the pre-Tertiary basement and folded the overlying Tertiary sediments. A significant uplift and tight folding, followed by erosion, removed most of the Tertiary rocks in the Sava Folds area. In central and northern Slovenia, the inversi-




Sl. 2.13. Topografija osrednje Slovenije z Ljubljansko kotlino in njeno širšo okolico. Jasno je viden topografski odraz dinarskih prelomov s smerjo NW-SE v jugozahodnem delu. *Marko Vrabec*

Fig. 2.13. Topography of central Slovenia with Ljubljana basin and its broad surroundings. Note the clear topographic expression of NW-SE-trending Dinaric faults in the southwestern part. *Marko Vrabec*

nega sistema je ocenjen na okrog 100 km. Poleg tega je bilo ozemlje severno od preloma pri ekstruziji in ekstenziji Panonskega bazena še dodatno raztegnjeno, tako da znaša ocenjeni razmik ob Periadriatskem prelomu med predoligocenskimi geološkimi enotami okoli 300 km. Predekstruzijsko paleogeografijo severne Slovenije - npr. zaledje Dinarskega narivnega sistema - je torej zelo težko rekonstruirati, predvsem zaradi

on resulted in dextral transpression. Probably in this stage the dextral Sava fault in central Slovenia was activated, displacing the Karavanke and Kamnik-Savinja Alps by 30–40 km to the east. The uplift of the Karavanke mountains and their thrusting over the foreland probably also occurred in the Pliocene-Quaternary inversion period. Locally, small intra-montane basins formed along the strike slip faults, which were filled by

Sl. 2.14. Pogled iz zraka na Ljubljansko barje - široko tektonsko udorino nastalo pred približno dvema milijonoma let pri pogreznitvi obsežnega dela ljubljanske kotline. *Primož Komel*

Fig. 2.14. Aerial view on Ljubljana moor - a wide tectonic depression which was formed about two million years ago by subsidence of an extended part of the Ljubljana basin. *Primož Komel*

Sl. 2.15. V pleistocenu se je Bohinjski ledenik po izhodu iz ozke doline razširil po ravnici med Bledom in Radovljico in s svojim delovanjem močno preoblikoval pokrajino. Izdolbel je kotanjo Blejskega jezera, izravnal pokrajino in ob zastojih med umikanjem odložil končne morene. *Igor Košir*

Fig. 2.15. After exiting the narrow valley, the Bohinj glacier has spilled across the plateau between Bled and Radovljica in Pleistocene thus affecting significantly the evolution of the landscape. It carved out the hollow of the Bled lake, evened the landscape, and during its retreat deposited several terminal moraines. *Igor Košir*

tega, ker premaknjene kamnine severnega krila Periadriatskega preloma ležijo večinoma pod debelim pokrovom miocenskih sedimentov v Panonskem bazenu Madžarske.

Neogensko krčenje ozemlja v Jadransko-Evropski kolizijski coni je v Alpah južno od Periadriatskega prelomnega sistema sprožilo narivanje od severa proti jugu. To narivno epizodo imenujemo Južnoalpsko narivanje, ki se je začelo v srednjem miocenu in je do pliocena v glavnem zamrlo, čeprav na območju Julijskih Alp in njihovega predgorja verjetno poteka še danes. Na ozemlju Slovenije pripada Južnoalpskemu narivnemu sistemu območje Julijskih in Kamniško-Savinjskih Alp. Južnoalpsko narivanje je prekrilo in deformiralo starejše dinarske narivne strukture, kar je pri nas dokumentirano na območju Blegoša.

Na prehodu iz miocena v **pliocen** sta dokončno zaprtje oceanskega bazena v Karpatih in z njim povezana kontinentalna kolizija ustavila ekstruzijo Vzhodnih Alp proti vzhodu. Zaustavitev ekstruzije je povzročila temeljito reorganizacijo tektonskih dogajanj na tem območju, novo vzpostavljeni tektonski režim pa traja še danes. Podatki paleomagnetizma kažejo, da je v tej fazi Jadranska plošča začela rotirati v smeri, nasprotni urnim kazalcem. V Panonskem bazenu se je ugrezanje bazena dokončno ustavilo, pritisk zaradi primikanja in rotacije Jadranske plošče pa je povzročil tektonsko inverzijo - reverzno reaktivacijo bazenskih normalnih prelomov in dviganje tektonskih blokov ob njih. Ti premiki so povzročili gubanje terciarnih sedimentov v Posavskih gubah ter dvig hrbtov in blokov v vzhodni Sloveniji z gubanjem in erozijo miocenskih sedimentov nad njimi. V osrednji Sloveniji je inverzijska faza povzročila desno transpresijo z zmičnimi premiki ob strmih prelomih in sočasnim krčenjem ozemlja v smeri sever-jug. V tej fazi je verjetno postal aktiven Savski prelom v osrednji Sloveniji, ob katerem je prišlo do 30–40 km desnega zmika, ki je premaknil ozemlje Karavank in Kamniško-Savinj-

Sl. 2.16. Kapelica v Bovcu, poškodovana med velikonočnim potresom leta 1998. *Stanko Buser*

Fig. 2.16. Small chapel in Bovec damaged during the Easter earthquake in 1998. *Stanko Buser*

skih Alp proti vzhodu. Tudi dvig gorske verige Karavank in njihovo narivanje na predgorje sta verjetno povezana s pliocensko inverzijo. Ob zmičnih prelomih so ponekod nastali majhni intramontani bazeni, ki so jih zapolnili kontinentalni sedimenti z različno debelimi premoškimi horizonti (Velenjski bazen, udorine v okolici Kočevja).

V neogenu se je začelo tudi podrivanje (kontinentalna subdukcija) Jadranske plošče pod ozemlje Dinaridov. Narivne strukture te faze so bile odkrite v slovenski Istri in vzdolž Kraškega roba. Te strukture deloma prekrivajo in deformirajo starejše dinarske narivne strukture. Začetek podrivanja časovno za zdaj ni natančneje opredeljen, traja pa verjetno še danes.

**Kvartar**

Pleistocen se je začel pred dobrima dvema milijonoma let. Iz tega obdobja poznamo več ohladitev podnebja oz. ledenih dob z vmesnimi toplejšimi obdobji. Zadnja poledenitev se je končala pred 11.700 leti. Od takrat traja holocenska doba.

V **pleistocenu** so bili na slovenskem ozemlju ledeniki, ki so segali z Julijskih in Kamniško-Savinjskih Alp ter Karavank v predgorje. Tektonsko ustvarjene nižine so se v pleistocenu polnile z rečnimi in jezerskimi sedimenti, ki so ponekod debeli tudi do 120 metrov.

V kvartarju se je iz pliocena nadaljeval tektonski režim inverzije. O še vedno aktivnih tektonskih premikih na našem ozemlju pričajo številni potresi, dokazani pa so bili tudi z meritvami z GPS tehnologijo. Ti podatki kažejo, da se nadaljuje podrivanje Jadranske plošče, ki ga spremlja narivanje proti jugu, ter reverzni in desnozmični premiki ob ENE–WSW do NW–SE usmerjenih prelomih.

V kvartarju se je izoblikovala sedanja pokrajinska podoba Slovenije.

continental sediments containing coal deposits (the Velenje Basin and the basins around Kočevje).

In the Neogene, the underthrusting of Adria under the Dinarides had begun. The related thrust structures, which were documented in Slovenian Istria, overprint the older Dinaric thrusts and folds. The more precise timing of the onset of Adria underthrusting has not been constrained yet.

**Quaternary**

In the **Pleistocene**, the Alpine glaciers from the Julian Alps, Kamnik-Savinja Alps, and Karavanke mountains were reaching into the foreland. Partly tectonically controlled depressions were filled with fluvial and lacustrine sediments, which are up to 120 m thick.

The compressional tectonic regime continued from the Pliocene into the Quaternary. The ongoing tectonic deformation is evidenced by significant earthquake activity and is also confirmed by GPS measurements of diplacements. The GPS data suggest a northward push of Adria relative to Eurasia, which drives southward thrusting into the Slovenian Alps and reverse and dextral motion on WNW–ESE to NW–SE oriented faults in the area north of Istria.

Sl. 2.17. Zatrep doline Ravenske kočne nad Zg. Jezerskim. *Stanko Buser*

Fig. 2.17. The gable-end of the Ravenska kočna valley at Zg. Jezersko. *Stanko Buser*

## LITERATURA / REFERENCES


BUSER, S. 1989: Development of the Dinaric and the Julian Carbonate Platforms and of the Intermediate Slovenian Basin (NW Yugoslavia). In: CARULLI, G. B., CUCCHI, F. & RADRIZZANI, C. P. (eds.), Evolution of the Karstic carbonate platform: relation with other periadriatic carbonate platforms. - Mem. Soc. Geol. Ital. 40 (1987), 313-320, Roma.

BUSER, S. 1996: Geology of Western Slovenia and its paleogeographic evolution. In: DROBNE, K., GORIČAN, Š. & KOTNIK, B. (eds.), The Role of Impact Processes in the Geological and Biological Evolution of Planet Earth. - International workshop, ZRC SAZU, 111-123.

BUSER, S., RAMOVŠ, A., DROVENIK, M. & PLENIČAR, M. 1998: Geološki razvoj Slovenije. In: JAVORNIK, M. (ch. ed.), Enciklopedija Slovenije, 3. zv. - Mladinska knjiga, 195-203, Ljubljana.

COUSIN, M. 1981: Les repports Alpes-Dinarides. Les confins de l'talie et de la Yugoslavie. - Societe Geologique du Nord, Publi. No 5, Vol. 1, 521 pp; Vol. 2 - Annexe, 521 pp.

FODOR, L., JELEN, B., MÁRTON, E., SKABERNE, D., ČAR, J. & VRABEC, M. 1998: Miocene-Pliocene tectonic evolution of the Slovenian Periadriatic Line and surrounding area: Implications for Alpine-Carpathian extrusion models. - Tectonics 17, 690-709.

FODOR, L., GERDES, A., DUNKL, I., KOROKNAI, B., PÉCSKAY, Z., TRAJANOVA, M., HORVÁTH, P., VRABEC, M., JELEN, B., BALOGH, K. & FRISCH, W. 2008: Miocene emplacement and rapid cooling of the Pohorje pluton at the Alpine-Pannonian-Dinaridic junction, Slovenia. - Swiss Journal of Geosciences, 2008, suppl. 1, vol. 101, 255-271.

MLAKAR, I. & ČAR, J. 2009: Geološka karta idrijsko-cerkljanskega hribovja med Stopnikom in Rovtami 1 : 25.000. (*Geological map of the Idrija-Cerkno hills between Stopnik and Rovte 1 : 25,000*). - Geološki zavod Slovenije.

PLACER, L. 1981: Geološka zgradba jugozahodne Slovenije. (*Geologic structure of southwestern Slovenia*). - Geologija 24/1, 27-60, Ljubljana.

PLACER, L. 2008: Principles of the tectonic subdivision of Slovenia. (*Osnove tektonske razčlenitve Slovenije*). - Geologija 51/2, 205-217, Ljubljana.

PREMRU, U. 2005: Tektonika in tektogeneza Slovenije - geološka zgradba in geološki razvoj Slovenije. (*Tectonics and tectonogenesis of Slovenia*). - Geološki zavod Slovenije, 518 pp., Ljubljana.

SCHMID, S. M., FUEGENSCHUH, B., KISSLING, E. & SCHUSTER, R. 2004: TRANSMED Transects IV, V and VI: Three lithospheric transects across the Alps and their forelands. In: CAVAZZA, W., ROURE, F., SPAKMAN, W., STAMPFLI, G. M. & ZIEGLER, P. A. (eds.), The TRANSMED Atlas: The Mediterranean Region from Crust to Mantle. - Springer Verlag.

SCHMID, S. M., BERNOULLI, D., FUEGENSCHUH, B., MATENCO, L., SCHEFER, S., SCHUSTER, R., TISCHLER, M. & USTASZEWSKI, K. 2008: The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. - Swiss Journal of Geosciences 101, 139-183.

VRABEC, M. & FODOR, L. 2006: Late Cenozoic Tectonics of Slovenia: Structural Styles at the Northeastern Corner of the Adriatic Microplate. In: PINTER, N., GRENERCZY, GY., WEBER, J., STEIN, S. & MEDAK D. (eds.), The Adria Microplate: GPS Geodesy, Tectonics and Hazards. - Nato Science Series: IV: Earth and Environmental Sciences, 151-168, Springer.