Milan Šifrer

NEKATERE SMERI IN POGLEDI GEOMORFOLOŠKEGA PROUČEVANJA NA SLOVENSKEM

Na Slovenskem je bila geomorfologija vseskozi domena geografskega proučevanja, uspešno pa so sodelovali na tem polju tudi geologi in strokovnjaki drugih sorodnih strok (paleolitičarji, polinologi, pedologi idg.) Že zgodaj je bilo mogoče dognati, da se stikajo na našem ozemlju štiri zelo obsežne zgradbene in tektonske enote (Alpe, Dinarsko gorstvo, Jadranska in Panonska udorina). Kaj kmalu smo dobili tudi že pregledno podobo o poglavitnih geoloških in kamninskih značilnostih našega reliefa. Dognalo se je, da prevladujejo skoraj v vsem našem visokogorskem svetu apnenci in dolomiti (Kamniške Alpe, Julijske Alpe, Dinarsko gorstvo). Ti sestavljajo tudi vse pomembnejše vrhove v Karavankah in v Alpskem predgorju, kjer se javljajo poleg njih v večjih količinah tudi starejši peščenjaki in skrilavci. Slabo odporni vododržni marinski sedimenti terciarnih morij pa se omejujejo predvsem na gričevnati svet na obodu Panonske in Jadranske udorine ter na nižje dele sinklinal in kotlin ob prehodu v Alpe in Dinarsko gorstvo (Melik, 1935, 1963. — V teh dveh virih je tudi pregled vse ostale ustrezne literature).

Pod vplivom Davisovih pogledov na razvoj reliefa se je zvrstila pri nas med obema vojnama in tudi še kasneje cela vrsta geomorfoloških razprav s poudarkom na genezi ravnikov in teras. Posebno zanimivost so pomenili obsežni ostanki uravnav, ki jih je mogoče ugotavljati skoraj v vsem ovršju našega reliefa. V slovenskem alpskem svetu se nahajajo v višinah 2300—2500 m, 1800 m, 1600 m, 1500—1550 m in 1100—1200 m, znatne višine dosegajo še v alpskem predgorju (800—1100 m) in v Dinarskem gorstvu (1000—1500 m), odtod se proti jadranski in panonski kotlini hitro znižajo na 800 m, 600 m, 550 m in še niže. Pod temi ravniki so ugotavljali posamezni avtorji še do 9 nižjih teras, vključujoč tudi pleistocenske (Melik, 1928, 1931, 1934, 1935, 1954 b, 1957, 1959a, 1960, 1963; Rakovec, 1931, 1933, 1939, 1951; Ilešič, 1938). Istega značaja so tudi številne mlajše razprave, ki so jih napisali Borut Belec, Ivan Gams, Božidar Kert, Vladimir Kokole, Drago Meze, Stanko Polajnar, Slava Lipoglavšek-Rakovec, Igor Vrišer in so citirane v že navedenih Melikovih knjigah.

Diskusija o morfogenezi najvišjih uravnjenih površin in nižjih teras je še ves čas odprta. Obsežne ravnike so tolmačili spočetka z abrazijo, vendar so bila pri nas ta tolmačenja močno osamljena (Nagode, 1931). Veliko bolj je prevladovalo mnenje, da so te oblike rezultat fluvialne erozije in da so tem širše, čim trajnejše je bilo obdobje tektonskega mirovanja. Najvišji in najširši ravniki naj bi torej nastali v obdobju najtrajnejšega tektonskega mirovanja. Izdelale naj bi jih reke tekoče iz Alp in dinarskega sveta v tedanje Jadransko in Panonsko morje. Do kasnejšega razčlenjevanja tega površja in nastanka številnih nižjih teras pa naj bi prišlo ob kasnejšem, čedalje pogostejšem in močnejšem dviganju alpskega in dinarskega sveta, ki bi ga prekinjale samo kratkotrajnejše faze mirovanja (te misli se javljajo v vsej že citirani literaturi). Sredi teh pogledov zasledimo v naših razpravah tudi že prve kritične ocene obstoječih kriterijev, ki opozarjajo, da geomorfološki razvoj ni bil tako enostaven in da bo treba vključiti v proučevanja tudi fluvialne in druge sedimente, ohranjene po terasah in planotah (Ilešič, 1937).

Novejše ugotovitve vidijo poglavitno pomanjkljivost prikazane sheme v tem, da računa samo s fluvialnimi procesi ter tektoniko, medtem ko ne upošteva cele vrste drugih faktorjev, n. pr. sprememb v kamninski sestavi površja, paleogeografskih dejstev, pa tudi klime (Gams, 1957, 1962; Šifrer, 1959, 1962a, 1964, 1970; Melik, 1963; Radinja, 1966, 1967, 1969). Po ugotovitvah novejših študij so bili v obdobju nastajanja obsežnih ravnikov pokriti s terciarnimi sedimenti, ki se omejujejo danes skoraj izključno samo na nižji svet, tudi obsežni predeli današnjega gorskega kraškega površja. Videti je, da je prišlo do poglavitnega nastajanja ravnikov šele po zelo obsežni miocenski in sledeči panonski transgresiji, ko so se zaradi tektonskih premikov in po teh povzročenih eksogenih procesov začele kazati, izpod tedaj še vedno na široko razprostranjenih terciarnih sedimentov, zaplate apniškega površja. To predstavo potrjujejo do danes ohranjene manjše krpe vododržnih terciarnih hribin po visokih kraških planotah, ki so docela podobne ustreznim kamninam v večjih in bolj sklenjenih arealih v nižjih nadmorskih legah (Grimšičar, 1954; Kokole, 1956; Pierau, 1958; Šifrer, 1962a, 1964, 1970; Radinja, 1966, 1969). Osvetljuje jo poleg tega tudi po apniških planotah in suhih dolinah ohranjeni prod, ki izvira iz vododržnih terciarnih sedimentov (različno obarvan kremen, tufi itd. — Germovšek, 1955; Gams, 1962; Šifrer, 1962a, 1907; Meze, 1966; Radinja, 1966, 1967, 1969 Habič, 1968). Iz odnošaja tega proda do danes docela kraških planot je bilo mogoče tudi ugotoviti, da so terciarni sedimenti tedaj ponekod tudi reliefno dominirali in ustvarjali v tako zajezenem apnencu ugodne pogoje za površinsko hidrografijo. O izdatnih učinkih teh rek v tedaj že razkritem apniškem površju pričajo med prodom iz terciarnih kamenin (različno obarvan kremen in tufi) ohranjeni tudi lepo zaobljeni prodniki z avtohtonega apniškega površja (roženci, limonit idg.). K pospešenemu uravnavanju in zniževanju apniškega površja pa je domnevno veliko prispevala tudi korozija. Ta je bila v topli pliocenski klimi, ko so ti ravniki nastajali, najbrže še posebno izdatna in je povzročila, da se je apniško površje še posebno hitro, celo hitreje zniževalo kot vododržne terciarne kamenine.

Videti je, da je bil apnenec že takoj ob razkritju podvržen intenzivnim korozijskim procesom s tendencami uravnavanja ter usmerjene korozije v dnu rečnih dolin. To aktivnost izpričujejo različno stari boksiti, ki so se ohranili po kraškem površju in niso kot vemo nič drugega, kot fosilna kraška ilovica. Prav s tem kombiniranim delovanjem erozije, korozije in seveda tudi denudacije razlagamo pospešeno zniževanje apniškega površja in nastanek najširših ravnikov (Šifrer, 1962a, 1964; Radinja, 1966, 1967, 1969).

Pri še podrobnejši rekonstrukciji tedanjega reliefa in razširitvi teh proučevanj na vse slovensko ozemlje nam bodo poleg ostankov marinskih terciarnih sedimentov in proda v veliko oporo tudi sledovi številnih, že doslej zelo dobro raziskanih suhih dolin. Že dosedanja proučevanja so opozorila na fosilne sledove dolin v Kamniških Alpah in Karavankah ter na ostanke korit starih vodnih tokov, ki so tekli iz tedaj obsežne kotline terciarnih kamenin v območju Bohinja čez apniško Jelovico proti Ljubljanski kotlini. S tedaj reliefno najbrže dominantnih področij fliša v območju Vipavske doline, Pivške kotline in zaledja Kopra pa so tekle vode čez visoke kraške planote med Trnovskim gozdom in Snežnikom proti severovzhodu in vzhodu proti danes pretežno zakraselemu porečju Ljubljanice. Odtod pa so usmerjene suhe doline tudi proti Reškemu zalivu in matičnemu Krasu nad Trstom. Številne suhe doline so bile ugotovljene tudi v soseščini terciarnih sedimentov na Kočevskem polju, ob Mirni, zgornji Krki ter v Krški kotlini (Rus, 1925; Melik, 1931, 1934, 1935, 1951, 1954b, 1959a, 1960, 1961; Šerko, 1951; Gams, 1962; Šifrer, 1962a, Radinja, 1966, 1967, 1969).

Ob tem bo mogoče zbrati najbrže tudi veliko več dokumentacijskega gradiva o pogojih, v katerih je prišlo do razčlenjevanja teh ravnikov in do nastanka številnih teras, ki jih opazujemo vzdolž rečnih tokov in so jih tolmačili doslej samo z igro erozije in tektonike. Že iz dosedanjih raziskav je videti, da so ponehali ugodni pogoji za nastajanje ravnikov najbrže že takoj ob prvih znatnejših ohladitvah v zgornjem pliocenu. Površje v tedaj veliko bolj razprostranjenih vododržnih kamninah je postalo v tej klimi manj odporno in se je začelo hitreje zniževati, korozija na apnencih pa je oslabela. Vse to je pripeljalo do hipsografskih sprememb v razmerju med apnencem in vododržnimi terciarnimi kamninami. Z zniževanjem terciarnih marinskih sedimentov, ki so dotlej zajezevali apniško površje, so začele reke presihati in izginjati v kraško notranjost. Na osnovi fosilnih slepih dolin in robnih uravnav, ki so se nam ohranile iz tega obdobja, je mogoče sklepati, da je potekalo krčenje areala vododržnih terciarnih sedimentov zelo neenakomerno in da je prišlo ob zastojih do ponovnega nastajanja širših teras. Velike množine proda, ki so se ohranile po teh površinah opozarjajo na veliko aktivnost linearno tekočih voda.

Ob prehodu iz pliocena v pleistocen se je, po teh ugotovitvah, selektivna in linearna globinska erozija še okrepila. Iznad terciarnih sedimentov so se začele čedalje markantneje dvigati apneniške Alpe in Dinarsko gorstvo pa tudi Pohorje in najvišji deli Posavskega hribovja. Razkrila se je starejša tektonska zasnova in nekateri markantni še vse do danes aktivni prelomi. Iz zaključnih oddelkov tega obdobja so se ohranili na vznožju omenjenih gorstev široki »pedimenti« oz. »glacis«, ki se nahajajo okrog 100—300 m nad današnjim dnom dolin. Izdelani so pretežno v slabo odpornih terciarnih kameninah, deloma pa tudi v apnencih. Po njih ohranjeni debeli in petrografsko pretežno raznoliki, pa tudi razbiti in ponovno zaobljeni prod dovoljujejo domnevo, da so bili mehanični procesi v tedanji klimi zelo intenzivni (Šifrer, 1961b; Gams, 1962 Meze, 1964/65, 1969; Radinja, 1966). Na izredno selektivnost procesov v tem obdobju in na izredno akumulacijo pa lahko sklepamo tudi iz same ohranjenosti terciarnih marinskih sedimentov. Raziskave so pokazale, da so se ohranili le-ti bolj sklenjeno samo nekako do višine teh pedimentov, ki jim ustrezajo v glavnem tudi višine terciarnih goric v Panonskem obrobju, više pa samo v izjemnih primerih (npr. Brkini) in v lokalnih zajedah.

Zelo podrobnega študija je bilo deležno pri nas tudi samo pleistocensko obdobje s sledovi pleistocenske zaledenelosti in periglacialnih procesov ter ustreznega fluvioglacialnega in fluvioperiglacialnega nasipanja ter erozije, ki je poglobila naše doline za nadaljnih 100—300 m. Tovrstna proučevanja smo uvrstili v letu 1959 celo v osrednji program Inštituta za geografijo pri Slovenski akademiji znanosti in umetnosti v Ljubljani; prinesla so posebno k osvetlitvi periglacialne problematike naših krajev veliko novega (pri teh proučevanjih so sodelovali Borut Belec, Ivan Gams, Božidar Kert, Vladimir Kokole, Marko Kolbezen, Emil Kolenik, Jelka Kunaver, Jurij Kunaver, Drago Meze, Darko Radinja, Stanko Polajnar, Zvonko Rus, Anton Sore, Milan Šifrer in Marijan Žagar).

Pregledno sliko zaledenelosti naših Alp smo dobili že pred prvo svetovno vojno (Penck-Brückner, 1901—1909). Kasneje je sledila cela vrsta razprav, ki so to podobo močno dopolnile. To ne velja samo za Julijske Alpe, kjer se je zbirala glavnina ledu v soškem in bohinjskem ledeniku ter v dolinah Radovne in Save Dolinke, marveč še veliko bolj za Karavanke in Kamniške Alpe, kjer je bila poledenitev veliko manj obsežna in omejena na manjše ledenike. Ti so bili po svojem obsegu komaj kaj večji kot v Julijskih Alpah v bühlskem oziroma bohinjskem stadiju. Povsem nove so ugotovitve o zaledenelosti Olševe, Košute in Peščivca v Karavankah, južne strani Bohinjskega grebena in Ratitovca v Julijskih Alpah ter obsežnih ledenikov na Trnovskem gozdu in Snežniku, kjer je bila ločnica večnega snega v vsem slovenskem gorskem svetu najnižja (okrog 1200-1250 m - Melik, 1930, 1932, 1935, 1954, 1959, 1960; Šifrer, 1959a, 1961, 1969; Meze, 1964/1965, 1966; Gams, 1970; Habič, 1968).

Poleg moren würmske poledenitve so ugotovljene pri nas tudi morene treh obsežnejših starejših poledenitvenih obdobij (starejši würm ali mlajši riss oziroma samostojna poledenitev med würmom in rissom, riss in mindel), ki so ohranjene v kompletni seriji v čelni kotanji bohinjskega ledenika pri Radovljici in domnevno tudi v dolini Kokre (Šifrer, 1960a, 1969; Meze, 1964/1965). Drobnejšega študija so bili deležni tudi morenski nasipi umikalnih stadijev ter historičnih ledenikov (Penck-Brückner, 1901—1909; Melik, 1935, 1954, 1954b, 1963; Meze, 1955, 1964/1965;

1966; Šifrer, 1961, 1961a, 1963). Vzporedno s tem so potekala tudi proučevanja številnih fosilnih in obstoječih jezer, ki so nastala po planotah in v čelnih kotanjah za umikajočimi se ledeniki. Med obstoječimi ledeniškimi jezeri sta bili deležni Blejsko in Bohinjsko jezero še posebno sistematičnih raziskav (Melik, 1928, 1930, 1934, 1954, 1954b; Rakovec, 1929; Gams, 1962a; Meze, 1966; Šifrer 1969). Veliko pa se je razpravljalo tudi o ledeniški eksaraciji in o vlogi ledenikov pri izoblikovanju podobe naših Alp (Melik, 1954, 1955; Šifrer, 1959, 1969; Meze, 1966).

Po zadnji svetovni vojni smo razširili proučevanja tudi na periglacialna področja (Melik, 1955; Šifrer, 1959, 1960, 1961, 1969; Radinja, 1963; Meze, 1964/1965, 1966, 1969). Raziskave kažejo, da je bilo zadrževanje iglastih gozdov pri nas zelo dolgotrajno in da je prišlo do močnega znižanja gozdne meje in do razredčenja preostalega gozda šele ob skrajnih, najbolj ekstremnih viških poledenitvenih obdobij. Iz gozdnatih oddelkov ledenih dob so se nam ohranile plasti denudacijskih ilovic s pelodom in lesom severnjaške tajge, iz sledečih ekstremnejših obdobij pa debele plasti soliflukcijskega gradiva, ki pokriva pobočja tudi po več kilometrov stran od izvora (Melik, 1955; Šifrer, 1959, 1961, 1969; Šercelj, 1966, 1970). Periglacialnega drobirja je še posebno veliko v spodnjem Posočju ter v vsej dolgi barieri kraških planot, ki se vleče od Trnovskega gozda mimo Nanosa, Hrušice, Javornikov in Snežnika proti jugovzhodu, kjer je prišlo ob klimatskem stiku ohlajene kontinentalne notranjosti s toplejšim Mediteranom do zelo izdatnega mehaničnega razpadanja kamenin in soliflukcije. V notranjosti Slovenije zasledimo več tega gradiva samo v višinah nad 300 oziroma 600 m, niže pa seže le v ožjem obodu Panonske kotline in v Primorju, kjer je prišlo tudi do odlaganja puhlic (Melik, 1954; Šifrer, 1959a, 1960, 1961, 1963; Radinja, 1963; Meze, 1966, 1969). Izrazito stratificirano periglacialno pobočno gradivo smo našli doslej samo v območju bohinjskega ledenika, kjer je prišlo tudi v toplejših delih leta najbrže samo do transportiranja drobirja po spodaj ležeči zamrznjeni plasti, podrugod, kjer je bilo odtajanje tal globlje in so se vode hitreje odtekle v notranjost pa je debelejši drobir kratkomalo pomešan z drobnejšimi delci. Določeno usmerjenost je opaziti le pri večjih skalah, ki so zaokrenjene z daljšo osjo v smeri naklona pobočij (Šifrer, 1959, 1960, 1961, 1969; Radinja, 1963; Meze, 1966, 1969).

Cryoturbatni pojavi (žepi, ledeni klini idg.) so pri nas bolj redki, vendar jih je bilo mogoče ugotoviti doslej tudi že na več krajih (Šifrer, 1959a, 1961, 1969; Brodar, 1960).

Zelo številne so pri nas tudi študije o pleistocenskih terasah. Dolgo časa so se omejevale tovrstne raziskave samo na širokopotezna nasipanja vzdolž glavnih alpskih rek, po zadnji vojni pa smo razširili naš pogled tudi na pritoke izven območja pleistocenske poledenitve in ustreznega fluvioglacialnega nasipanja. Širokopotezna nasipanja v glavnih alpskih dolinah smo tolmačili spočetka s tektoniko. Ti pogledi so se pojavljali tudi pozneje, ko so bile v svetu in tudi pri nas že močno osvojene nove teorije, po katerih bi se v poledenitvenih oddelkih ledenih dob Alpe nekoliko ugreznile, s tem naj bi se zmanjšal strmec dolin in bi nastali ugodni pogoji za akumulacijo. V toplejših oddelkih pleistocena pa naj bi bilo zaradi umikanja ledenikov in s tem povezanega dviganja Alp prišlo do erozije (Penck-Brückner, 1901—1909). Sredi vseh teh pogledov so se pojavljala pri nas tudi že docela klimatska tolmačenja teh nasipanj. Povezovali so jih podobno kot danes s samimi poledenitvami, ki ustvarjajo z zelo zapletenimi procesi toliko proda, da ga izpod ledenikov tekoče vode niso sposobne sproti odnašati in ga zato veliko odlože v vršajih že takoj neposredno pred ledeniki. Do erozije pa bi prišlo v sledečih obdobjih, ko so se ob taljenju ledenikov sprostile velike množine vode in so ponehali tudi drugi procesi, ki so v predhodni dobi povzročili nasipanje (Melik, 1933, 1934, 1939a; Rakovec, 1932; Šifrer, 1959, 1959a, 1961, 1969; Meze, 1964/1965, 1966, 1969).

Ob glavnih alpskih rekah (Muri, Dravi, Savi in Soči) so ugotavljali različni raziskovalci v bližini ledenikov do 4 skrajno hladnodobne terase in do 3 kasnoglacialne. S približevanjem teh rek Panonski nižini se je računalo le še nekako z dvema vodilnima pleistocenskima terasama (Penck Brückner, 1901—1909; Winkler, 1926—1927; Melik, 1930, 1934b, 1937, 1959; Ilešič, 1935; Šifrer, 1961, 1969; Meze 1966). Novejša proučevanja opozarjajo na precej večje število pleistocenskih teras. Računa se s 6. oz. 7. skrajno hladnodobnimi in 3—5 kasnoglacialnimi terasami in tako tudi s precej večjo pleistocensko poglobitvijo dolin, kot se je domnevalo to doslej (Winkler, 1955; Šifrer, 1959, 1964, 1969, 1969a; Meze, 1966, 1969). Pri datiranju najvišjih od njih (4, 5, 6 in 7) se sklicujejo avtorji predvsem na to, da je prod v njih vzdolž istih rek docela podoben produ v nižjih terasah (3, 2, 1 in kasnoglacialnih a, b, c, d, e), ki se navezujejo na ustrezne morenske nasipe. Opozarjajo na podobno debelino, kamninsko sestavo pa tudi zaobljenost te nasutine. Celo v najvišjih terasah so v njej do kraja prepereli samo karbonati in je tako v nasprotju s starejšimi nasipanji še vedno zelo pestre kamninske sestave. Meritve zaobljenosti po izpopolnjeni Cailleuxovi metodi pa so pokazale, da pride največ prodnikov v stolpce med 51 in 250, torej v drugega, tretjega, četrtega in petega; glavni višek pa je v četrtem stolpcu. To velja tudi za prod v najvišjih treh terasah (5, 6 in 7) v katerih so karbonati že do kraja preperelí, prav tako pa tudi za prod, ki smo ga zaradi primerjave jemali iz prepereline po nižjih terasah (1, 2, 3, 4). Ker vemo, da je ta zaobljenost značilna za fluvioglacialni prod, so postale zgoraj postavljene domneve o pleistocenski starosti obravnavanih teras še bolj verjetne (Šifrer, 1969a).

Pri nižjih terasah (3-mlajši krovni prod, 2-visoka terasa in pri dveh nizkih terasah 1_1 in 1_2 so nas opozorile na zvezo nasipanj z ledeniki še ugotovitve, da se začno terase s približevanjem morenam zelo hitro dvigati in skoraj neopazno preidejo vanje ter da se ob njih tudi končujejo. Prod postane skoraj povsem nesortiran ter so mu primešane tudi posamezne prav debele, med njimi tudi skoraj povsem neobdelane skale in obilica peščenega gradiva. Različno obarvani apniški prodniki dajejo v bližini moren veliko bolj kontrasten videz, kot bolj stran od njih, kjer se siva prevleka, ki nastane na produ pri udarcih ob transportu v rekah, razpotegne po vsej površini. Sočasnost poledenitev ter ustreznih nasipanj smo dokumentirali tudi z podobno debelino in značajem prepereline na istodobnih morenah in zasipih, s stopnjo preperelosti silikatnega drobirja, ki se je ohranil v preperelini, z različnimi korozijskimi formami, ki so nastale na stiku med preperelino in morensko oz. prodno podlago (korozijski žepi, kraške jame, vrtače itd.), kot tudi s samo svežino oziroma z značajem zlepljenosti posameznih moren in zasipov. Na tej osnovi smo izvršili doslej posebno ob Savi in ob pritokih v Ljubljanski kotlini pa tudi navzdol ob njej zelo drobno razčlenitev različno starih moren in ustreznih nasipov (Šifrer, 1960a, 1961, 1969; Meze, 1964/1965, 1969).

Tudi erozijo, ki loči posamezne zasipe med seboj smo v zadnjih letih tolmačili skoraj docela s klimo (Melik 1930; Rakovec, 1952; Šifrer, 1959, 1961, 1969, 1969a; Meze, 1964/1965, 1966, 1969). Do vsakokratne erozije bi prišlo, podobno kot po zadnji ledeni dobi, ob samem umikanju ledenikov. Po najnovejših dognanjih pa bi se nadaljevala bočna, deloma pa tudi globinska erozija tudi še v same sledeče poledenitvene oddelke ledenih dob (Šifrer, 1969). Za slednje govori predvsem dejstvo, da so se ohranili sledovi širokopoteznega fluvioglacialnega nasipanja na širokih živoskalnih policah in da ni najti med fluvioglacialnim prodom in živoskalno podlago prav nikjer toplodobnih sedimentov. Ti se omejujejo le na območja lokalnega tektonskega grezanja (npr. na Ljubljanskem barju) oziroma na večja jezera, ki so se zadrževala v ledeniških čelnih kotanjah še daleč v sledeča topla obdobja. Še posebno obsežno tako jezero je obstojalo med zadnjima poledenitvenima obdobjema v Blejsko-radovljiški kotlini (zadnja poledenitvena faza je nesporno würmska, za starejšo pa je še odprto ali gre za starejši würm ali pa mlajši riss, ali pa celo za samostojno poledenitev med würmom in rissom.) Prod v teh deltah je podobno zaobljen kot recentni in tako veliko bolj kot fluvioglacialni (Šifrer, 1969).

Tu naj opozorimo tudi na raziskave številnih ilovnatih in peščenih sedimentov na robu širokih ravnin nasutih s fluvioglacialnim prodom, ki so jih imeli doslej skoraj izključno le za sedimente jezer. Le ta bi nastala v zatišju pred širokopoteznim nasipanjem ledeniških rek. Novejša proučevanja so opozorila, da so ti sedimenti pogosto fluvialnega in denudacijskega porekla (Šifrer, 1961, 1969; Meze 1966). Bolj zatrdno je bilo mogoče dokazati doslej jezerski značaj teh sedimentov le na Ljubljanskem barju, ki je bilo deležno zaradi bližine Ljubljane in v zvezi z mostiščarji še posebno podrobnih raziskav (Rakovec, 1938; Melik, 1946 – V tem delu je zbrana tudi obsežna starejša literatura; Šercelj, 1966).

Tudi v dolinah izven neposrednega vpliva glaciacije oz. fluvioglacialnega nasipanja je bilo mogoče dognati globoko pleistocensko erozijo (100—300 m) s 6 oziroma 7 terasami. Proučevanja v alpskem svetu so pokazala, da je bil debel prod, ki so ga prenašale v tem obdobju reke, še posebno odločilen za erozijo in da je prišlo v periglacialnih obdobjih do močnega zasipanja dolin in delne lateralne erozije, v sledečih toplih obdobjih pa do intenzivnega globinskega vrezovanja. Teh dognanj tudi razširitev proučevanj na ostala področja Slovenije ni bistveno spremenila, je pa prinesla veliko tehtnih dopolnitev. Predvsem so ta razširjena proučevanja opozorila, da erozija, ki se je začela tudi po zadnjem fluvioperiglacialnem nasipanju, nikakor ni tako enostavna. Tekom holocena so jo prekinjale številne doslej še vse premalo proučene akumulacije proda, peskov in ilovic, ki jih reke posebno v srednjih in deloma tudi v dolnjih delih dolin še do danes niso utegnili razrezati. Nobenega dvoma ni, da moramo računati s tovrstnimi procesi tudi v starejših toplih obdobjih. Vendar se ti sedimenti skoraj niso ohranili. Povsod smo ugotavljali, da leži po terasah odložen fluvioperiglacialni prod neposredno na živoskalni podlagi. V lokalno ohranjenih peskih in peščenih ilovicah, ki so se ohranile vmes, pa smo našli samo pelod in makroorganske ostanke severnjaške tajge. Teh dejstev skoraj ni mogoče tolmačiti drugače, kot da se je nadaljevala erozija še iz toplih obdobij v hladna in pri tem odstranila predhodno odložene toplodobne sedimente. Videti je, da je prešla ta erozija postopoma iz globinske v bočno. To se je zgodilo v glavnem najbrže šele ob skrajnih viških poledenitvenih obdobij, ko je prišlo zaradi sušnosti in obilnega dotoka periglacialnega drobirja v doline do akumulacije. S tem drobirjem so se posebno na debelo zasipali zgornji deli dolin, veliko pa se ga je odložilo tudi v vršajih, ki so nastali ob vstopu potokov iz hribovja v kotline. V slabo odpornih terciarnih kameninah, ki se tu pojavljajo, je prišlo pri prestavljanju potokov iz ene strani vršaja na drugo do izredno močnega bočnega vrezovanja. Toda tudi v teh obdobjih globinska erozija najbrže ni povsem ponehala, kot smemo sklepati iz hitrega stanjšanja debeline prodnega nanosa v spodnjem delu teh vršajev in dejstva, da se tu v nasutini nenadoma močno poveča množina kamninskih kosov iz živoskalne podlage. Iz teh dognanj je bilo mogoče sklepati, da je bila globinska erozija tekom kvartarja močno prevladujoč proces in da je bila celo v periglacialnih obdobjih prekinjena pri večini periglacialnih rek samo v zgornjih delih dolin (Šifrer, 1961 b).

Ob vprašanju, kakšno vlogo je pri vsem tem zgornjepliocenskem in kvartarnem razvoju reliefa odigrala tektonika, novejša proučevanja zavračajo tezo, po kateri bi nastajale ravnote v ovršju našega reliefa v obdobju dolgotrajnega tektonskega mirovanja in to prav malo nad gladino tedanjih morij ter da bi bile dvignjene v današnje višine šele s kanejšo tektoniko. Čedalje bolj se vsiljuje predstava, da je bil dinarski in alpski svet v obdobju nastajanja teh ravnikov že znatno dvignjen, širokih oblik in v glavnem še nerazrezan. Pri tem se pogosto opozarja na podobne razmere, ki jih opazujemo danes v tropskih področjih. Tam se lahko vzpnemo tudi v prav znatne višine, še čez 1000 m in 1500 m, ne da bi opazili globlja erozijska korita. Zaradi tako močno dvignjenega reliefa je prišlo lahko do erozije že takoj ob prvih močnejših ohladitvah in obdobni sušnosti v zgornjem pliocenu, ko je prišlo do intenzivnega mehaničnega razpadanja kamnin, selektivne erozije in vseh že prikazanih procesov, ki so pospeševali globinsko erozijo. In tudi ohranjeni, uravnjeni ostanki starega površja so lahko v različnih višinah, ne da bi bilo treba klicati na pomoč tektoniko. Seveda se računa z delnimi splošnimi dvigi tudi še kasneje. Prišlo pa je tudi še do lokalnih dviganj in grezanj, pa tudi gubanj, celo kvartarnih sedimentov. Vendar so slednji premiki, kot je mogoče sklepati iz dosedanjih proučevanj, v velikem vendarle lokalizirani na ožja področja (Gams, 1957; Melik, 1963, Šifrer, 1961, 1964; Meze, 1966; Radinja, 1966, 1967). Poleg že doslej znanih metod je bilo mogoče dokazati te premike tudi s študijem dejanskih in docela teoretskih podolžnih rečnih profilov (Ilešič, 1951, 1952) pa tudi s študijem abrazijskih teras v Slovenskem Primorju (Šifrer, 1965). Vsa ta premikanja so prav gotovo še pospešila erozijo, katere intenzivnost so utemeljevali nekateri raziskovalci tudi s številkami o intenzivnosti recentnega preoblikovanja in z meritvami korozijske intenzitete, ter opozarjali s tem tudi na to, da je naš relief razmeroma mlad (Gams, 1957, 1963, 1967).

Proučevanja pa so bili deležni tudi še nekateri drugi pojavi in procesi v našem reliefu. Že od leta 1945 redno opazujemo ledenika na Triglavu in na Skuti, ki sta v stalnem umikanju. Drobne raziskave so bila deležna tudi snežišča in sledovi recentnega preoblikovanja sveta nad gozdno mejo (Drago Meze, 1955; Gams, 1961; Šifrer, 1961, 1961a). Redno smo spremljali tudi pomembnejše katastrofe in njih učinke. V tej zvezi smo proučevali snežne plazove ter učinke številnih neurij in povodnji (plazovi, usadi, podori, erozija idg. — Lit: Melik s sodelavci, 1954; Gams, 1955; Šifrer, 1962; Sore, 1963; Radinja, 1971).

Milan Šifrer

SOME DIRECTIONS AND IDEAS IN THE GEOMORPHOLOGICAL RESEARCH IN SLOVENIA

In Slovenia geomorphology has been always a domain of research of geographers although specialists from other fields of knowledge, notably geologists, have also succesfully joined them as well as specialists in early prehistory, in pollen research, in soil research, etc. It was found out quite early that four very large structural geological units meet in the area of Slovenia: the Alps and the Dinaric Mountains, the Adriatic and the Pannonian depressions. Also, it was at an early period of modern systematic research that an overview of the basic geological and lithological characteristics of the landforms of Slovenia was provided. It was found out that most of the high mountains in the country consist of limestones and dolomites (the Julian and the Kamnik Alps, the Dinaric Mountains). These also are the rocks of which all major peaks are made. They are predominant also in the Karavanke Mountains and in the subalpine mountains where, however, older sandstones and shales also appear over considerable stretches. Less resistent and impervious marine sediments of the tertiary seas are limited mostly to the hill-country on the rim of the Pannonian and of the Adriatic depressions, but they also appear in narrow belts in the synclines and basins on the contact of the Alpine and Dinaric mountain systems (Melik, 1935, 1963, see also the literature cited in the two books).

A series of studies focusing on the origin of the planation sufaces and terraces has been published, both before and after World War II. All were strongly influnced by Davis's views on the evolution of the landforms. Special attention was paid to the quite extensive remnants of planation which can be traced almost in all parts of Slovenia close to the level of the peaks. In the Alps, such planation surfaces are to be found at the altitudes of some 2300 to 2500 metres, 1800 m, 1500—1600 m and 1100 to 1200 m above sea-level. They still reach considerable heights in the subalpine mountains (800 to 1200 m) and in the Dinaric mountains (1000 to 1500 m), but their altitude declines rapidly both towards the Pannonian and towards the Adriatic basins, to 800, 600, 550 m or even less. Below these assumed peneplain remnants individual authors have indentified up to nine more terrace levels including the pleistocene terraces (Melik, 1928, 1931, 1934, 1935, 1954b, 1957, 1959a, 1960, 1963; Rakovec, 1931, 1933, 1939, 1951; Ilešič, 1938). Such was also the character of the numerous recent studies by Belec, Gams, Kert, Kokole, Meze, Polajnar, Lipoglavšek-Rakovec and Vrišer which are all referred to in both books by Melik.

The disscussion about the origin of landforms of the higher planation surfaces and of the lower lying terraces remained open throughout the past period. At the beginning of modern research the extensive planation surfaces or peneplains were ascribed to marine erosion (Nagode, 1931). This explanation, however, remained quite exceptional. Much more predominant is the view that such landforms were the result of river erosion and that their extension and the width correspond to prolonged periods of tectonic still-stand. The highest and the most extended to cover also the fluvial land other sediments preserved on the longest still-stand and would have been eroded by rivers flowing from the Alps and from the Dinaric Mountains to the Adriatic and to the Pannonian seas of that time. The following dissection of the peneplains and the formation of numerous river terraces would have resulted from the successive and increasingly more and more frequent uplifts of the Alpine-Dinaric area, broken only by short intervals of still-stand. These ideas are evident in all literature that was referred to above. But the first critical evaluation of the views that were predominant have also appeared and it was suggested that the evolution of the landforms might not have been quite as simple and that research should have been extended to cover also the fluvial and other sediments preserved on terraces and plateaus (Ilešič, 1937).

In the light of the more recent research the main shortcomings in the model of evolution as described above is the fact that only processes of river erosion and tectonic movements were considered, while several other factors, the differences in rock composition, paleogeographical sequence, but also climate, were neglected (Gams, 1957, 1962: Šifrer, 1959, 1962a, 1964, 1970; Melik, 1963; Radinja, 1966. 1967, 1969). These new studies have shown that, at the time when the supposed peneplain began to take form, large areas of the Alpine-Dinaric system were covered by much more extensive layers of tertiary sediments which, at present, are limited almost exclusively to lower parts of Slovenia; this was true even of considerable stretches in the high mountains karst areas. It appears that the planation surfaces began to be formed on a larger scale only after a very wide spread transgression in the miocene and in the following pliocene periods, when stretches of the limestone surfaces began to crop out of the still extensive cover of tertiary sediments due to tectonic uplifts and to exogeneous processes caused by them. This view is confirmed by the discovery of small patches of impervious tertiary rocks on the karst plateaus which do not differ from those found in much larger contiguous areas at lower altitudes (Grimšičar, 1954; Kokole, 1956; Pierau, 1958; Šifrer, 1962a, 1964, 1970; Radinja, 1966, 1969). Further evidence is provided by the gravel found on karst plateaus and in the dry valleys, which was derived from the impervious tertiary sediments (flints coloured in various tints, tuffas: etc. See: Grmovšek, 1955; Gams, 1962; Šifrer, 1962a, 1964, 1970; Meze 1966; Radinja, 1966, 1967, 1969; Habič, 1968). The relation of these gravels to the plateaus, which are by now entirely karstic, has made also possible to establish that the tertiary sediments were at that time also dominant in the landscape and have provided conditions for the surface hydrography. Substancial effects of the river action on the largely uncovered limestone surfaces of that period are demonstrated by the well rouded pebbles derived the allogenous karst stretches (hornstones, limonites, etc.) found among other gravel derived from tertiary rocks (coloured flints, tuffas). It is assumed that the corrosion has also greatly contributed to the accelerated planation and lowering of the limestone karst surfaces. The corrosion during the warm pliocene climate, when the extensive planation surfaces were in the process of formation, was probably very substantial and has led to rapid lowering of the karst terrains where it was even quicker than on impervious tertiary rocks. It appears that the limestones, when exposed, were from the start subject to an intensive corrosion process with the tendencies of planation and of the directed erosion at the bottom of the valleys. This activity is manifested in the boxites of various age that were preserved on the karst surface and which are simply fossil karst clay. It was exactly this combined performance of erosion, of corrosion and, of course, of denudation that explains the accelerated lowering of the karst surfaces and the origin of the most extensive areas of the planed surfaces (Šifrer, 1962a, 1964; Radinja, 1966, 1967, 1969).

The traces of numerous blind valleys, which have been studied already quite well, will be of great help in an attempt at an even more detailed reconstruction of the past landforms and in the extension of the studies to the entire area of Slovenia. The same is true of the remnants of the marine tertiary sediments and of the gravels. Already, the research caried out until now has drawn attention to fossil traces of the valleys in the Kamnik Alps and in the Karavanke mountains and to the remnants of the river beds of former water courses flowing from the area of the once much wider basin filled with tertiary rocks at Bohinj accross the limestone plateau of Jelovica toward the Ljubljana basin. The waters from the flysch heights in the present area of the Vipava valley, of the Pivka basin and of the flysch hills beyond Koper have also been flowing across the elevated karst plateaus between Trnovski gozd and Snežnik mountains toward East and North-east, i. e. toward the present karst area in the drainage basin of the Ljubljanica river. Dry valleys are also oriented toward the Gulf of Rijeka and toward the Kras (»Karst«) region above Trieste. Numerous dry valleys were also identified close to the tertiary sediments in the present polje of Kočevje, along the upper Krka and Mirna valleys and in the Krško basin (Rus, 1925; Melik, 1931, 1934, 1935, 1951, 1954b, 1959a, 1960, 1961; Šerko, 1951; Gams 1962; Šifrer, 1962a, 1970; Radinja, 1966, 1967, 1969).

It well be probably possible, by further research as indicated above, to accumulate more information about conditions which were in effect when the dissection of the wide planation surfaces viz. peneplains and the formation of numerous terraces was in operation. Even the studies carried out until now have indicated that the favourable conditions for the formation of the extensive planation surfaces came to an end probably as soon as the climate became considerably colder in the late pliocene period. In such a climate the surfaces on impervious rocks, which have been much more wide spread at that time, were becoming less resistent and tended to be lowred more rapidly, while corrosion on limestones was weakened. All this has led to height differences between limestones and impervious tertiary rocks. The lowering of the tertiary marine sediments, which have been blocking the limestone areas until then, has caused the rivers to dry up and to disapear into the karst underground. It is possible to conclude — on the basis of the fossil dry valleys and of the peripheral planation surfaces which remained preserved from that period — that the reduction of the areas covered by impervious tertiary sediments was very uneven and that, in periods of stagnation, the formation of wide terraces has started again. Large amounts of gravel that are preserved on such surfaces indicate strong action by linear water courses.

According to studies mentioned above the selective erosion and the linear erosion was strengthened in the transitional time-span between the pliocene and the pleistocene periods. The Alps and the Dinaric Mountains, built mostly of limestones, but also Pohorje and the highest parts of the Sava mountains began more and more markedly to crop out of the blanket of the marine tertiary sediments. The older structural geological features, notably the fault-lines (some of which are active even to-day) were thus exposed. Wide »pediments« or »glacis« forms at an altitude of some 100 to 300 metres above the present valley bottoms — which were formed at the foot of these emerging mountains during the last stages of this transitional period — are still preserved in many places. These forms are cut mostly into the little resistent tertiary rocks, but also in limestones. Coarse gravel of various lithological origin, but also pebbles broken or repeatedly rounded suggest that mechanical processes were very strong in the climatic conditions of that time (Šifrer, 1961b; Gams, 1962; Meze 1964—1965, 1969; Radinja, 1966). How extremely selective were the processes in that period and how extensive was the deposition can be deduced from the distribution of the remaining tertiary sediments. It was proved by recent research that the more contiguous areas of these sediments only reach the height of the above mentioned pediments which generally correspond to the heights of the tertiary hills on the Pannonian rim of Slovenia. Tertiary sediments are at greater altitudes only in exceptional cases (e. g. in the Brkini hills) or in small local wedges.

The pleistocene period was studied in rather great details in Slovenia. Considerable traces of the pleistocene glaciation and of the periglacial processes remain and are manifested also in the corresponding fluvioglacial and fluvioperiglacial deposition and erosion which has deepened the valleys for another 100 to 300 metres. Since 1959 the systematic research on the pleistocene period is included into the long-term research programme of the Institute of Geography at the Slovenian Academy of Arts and Sciences in Ljubljana. The studies conducted in more than one decade have, in particular, thrown much new light on the periglacial processes in Slovenia. Many geographers contributed to this effort (B. Belec, B. Kert, V. Kokole, M. Kolbezen, E. Kolenik, Jelka and Jurij Kunaver, D. Meze, D. Radinja, S. Polajnar, Z. Rus, A. Sore, M. Šifrer and M. Žagar).

A general overview of the glaciation of the Alps in Slovenia dates back to the time before World War I (Penck-Brückner, 1901—1909). A whole series of studies that have followed have greatly sharpened the focus provided by Penck and Brückner. This is true not only of the Julian Alps (where most of the ice for the Soča and Bohinj glaciers as well as for those in the Radovna and upper Sava valleys had been accumulating) but even more so for the Kamnik Alps and the Karavanke mountains where glaciation was on a much smaller scale and limited to small glaciers. There, the glaciers were hardly any larger than those in the Julian Alps in the Bühl viz. Bohinj stage. Entirely new evidence on the glaciation of some mountains was assembled during the last decades (Olševa, Košuta, Plešivec in the Karavanke mountains; the southern slopes of the Bohinj ridge and Ratitovec in the Julian Alps; considerable glaciers on Trnovski gozd and Snežnik mountains, where the snow-line was at a lower altitude than anywhere else in Slovenia — about 1200 to 1250 metres only. (See: Melik, 1930, 1932, 1935, 1954, 1959, 1960; Šifrer, 1959a, 1961, 1969; Meze, 1964/65, 1966; Gams, 1970; Habič 1968).

Apart from the morains of the Würm glaciation the morains of the glaciers from the three more extensive older glacial periods were also discovered (older Würm or the earlier Riss, viz. a separate glaciation between Würm and Riss; Riss and Mindel). In the complete series they are preserved in the terminal basin of the Bohinj glacier near Radovljica and — possibly — in the valley of Kokra (Šifrer, 1960b, 1969; Meze 1964/65). The morains related to the recession stages or those of the still existing tiny glaciers were studied in great detail (Penck-Brückner, 1901—1909; Melik, 1935, 1954, 1954b, 1963; Meze, 1955, 1964/65, 1966; Šifrer, 1961, 1961a, 1963). Paralel research was also conducted on the numerous fossil or existing lakes that were formed on plateaus or in the terminal basins behind the retreating glaciers. The still existing lakes of Bohinj and Bled were studied systematically for decades (Melik, 1928, 1930, 1934, 1954, 1954b; Rakovec, 1929; Gams, 1962a; Meze, 1966; Šifrer, 1969). The role of the glacial erosion in general and, more particularly, of the glaciers on the formation of the landforms in the Alps of Slovenia was discussed at length (Melik, 1954, 1935; Šifrer, 1959, 1969; Meze, 1966).

After the last war exploration was extended to cover the periglacial areas of Slovenia (Melik, 1955; Šifrer, 1959, 1960, 1961, 1969; Radinja, 1963; Meze, 1964/65, 1966, 1969). The research has revealed that coniferous forests persisted for a long and that the tree-line was greatly lowered and the remaining woods thinned out only during the extreme peaks of the glacial periods. Layers of the denudation clay that were deposited in the wooded sections of the glacial periods and contain pollen and timber typical of the northern taiga, but also thick layees of the solifluction materials (debris) on the slopes that were formed during subsequent extreme climatic conditions were also found. In places they are several kilometres away from the original site (Melik, 1955;

Šifrer, 1959, 1961, 1969; Šercelj, 1966, 1970). Periglacial material is particularly plentiful in the lower Soča valley and in the entire barrier of karst plateaus extending from Trnovski gozd, Nanos, Hrušica and Javornik toward Snežnik in the Southeast. There, on the climatic contact of the cold continental interior of Slovenia and the warmer Mediterranean area, both the mechanical weathering of rocks and the solifluction were very strong. In the interior of Slovenia the periglacial material is generally more plentiful only at the heights of some 300 viz. 600 metres, but is also found at lower altitudes on the rim of the Pannonian basin where — just as on the Adriatic side — loess was also deposited (Melik, 1954; Šifrer; 1959, 1960, 1961, 1963; Radinja, 1963; Meze, 1966, 1969). Clearly stratified periglacial slope deposits were hitherto found in the area close to the Bohinj glacier. But even there only the shalow upper layers of detritus used to thaw during warmer parts of the day and the detritus was transported downwards on the frozen lower layer. In other parts of Slovenia, where debris were thawing more in depth and where the water quicker drained inside, the coarser detritus is all mixed up with smaller particles. A clearly visible direction can be identified only in the case of the larger rocks, the longer axis of which is paralel to the inclination of the slopes (Šifrer, 1959, 1960, 1961, 1969; Radinja, 1963; Meze, 1966, 1969).

The cryoturbatic phenomena (ice wedges, ice-lenses, etc.) are rather uncommon in Slovenia although it was possible to discover them in several places (Šifrer, 1959a, 1961, 1969; Brodar, 1960).

Numerous studies deal with the pleistocene terraces. For a long time such studies have been limited to large scale deposition areas along the main Alpine streams. Since the war, however, research was expanded to cover also the tributaries from areas not affected by the pleistocene glaciation and the related fluvioglacial deposition. The large-scale deposition in the principal Alpine valleys was first explained by tectonic movements. This view was repeated also later when — abroad and in Slovenia — new theories gained ground, according to which the Alps subsided a little during the maximum glaciation spells in the Ice Ages wich led to the lowering of the gradient of the river beds. This, in turn, forced the rivers to deposition. During the warmer spells, however, erosion resulting from de-glaciation and the related uplift of the Alps would have taken place (Penck-Brückner, 1901—1909). Entirely climatic explanations of the deposition have appeared during the last years in Slovenia, too. Just as in the present time the past depositions were linked to the glaciations which, due to very complex processes, have provided such amounts of gravel that the streams emerging from the glaciers could not concurrently carry them away and had, therefore, deposited them in alluvial fans right in front of the glaciers. The subsequent erosion, however would have been initiated by large amounts of water from the thawing glaciers and because other processes that were responsible for deposition were stopped or greatly reduced

(Melik, 1955, 1954, 1959a; Rakovec, 1952; Šifrer, 1959, 1959a, 1961, 1969; Meze, 1964/65, 1966, 1969).

Various studies could establish up to four terraces from the coldest glacial periods and up to three late glacial terraces along the main Alpine ricers in Slovenia (Mura, Drava, Sava, Soča). In their courses close to the Pannonian basin, however, only two main pleistocene terrases used, in general, to be distinguished (Penck-Brückner, 1901—1909; Winkler, 1926/27; Melik, 1950, 1954b, 1957, 1959; Ilešič, 1955; Šifrer, 1961, 1969; Meze, 1966). More recent studies point at a considerably greater number of the pleistocene terraces. As many as 6 to 7 terraces from the coldest glacial periods and 3 to 5 late glacial terraces are being distinguished and consequently it is now thought that the rivers have cut down considerably deeper than it was assumed before (Winkler, 1955; Šifrer, 1959, 1964, 1969, 1969a; Meze, 1966, 1969). In discussing the age of the highest terraces the authors stress the fact that the gravel in them, along the same rivers, is quite similar to that found in the lower terraces (3, 2, 1) and in those of the late Ice Age (i. e. terraces a, b, c, d, e) which are linked to the corresponding morains. They draw attention to the similar size and the lithology as well as to the roundness of gravel in this depositions. Even in the very highest terraces only carbonate gravel is totally weathered and is thus — because of the varied lithology — in contrast to even older depositions. The measurements of the roundness by the use of the improved Cailleux method have revealed, however, that most of the pebbles belong to the columns between 51 and 250, i. e. to the second, third, fourth and the fifth column, with a peak in the fourth column. This is true even of the three highest terraces (5, 6 and 7) where the carbonates are entirely weathered, but also of the gravel samples that were taken — in order to enable comparsion — from the soil on the lower terraces (1, 2, 3, 4). Since we know that such roundeness is typical of the fluvioglacial gravel, the assumptions concerning the pleistocene age of the terraces referred to obave have become even more convincing (Šifrer, 1969a).

Closer to the morains the lower terraces (3 = the »younger cover gravel«, 2 = the »high terrace«, 1_1 and 1_2 = two lower terraces) begin quickly to rise and pass over into them almost invisibly where they also end. This indicates a relation between the glaciers and the deposition. Closer to the morains the gravel is also hardly sorted out and plenty of large pebbles and sand of different colour produce a much more variagated picture of the gravel that in areas further away from the morains where the grey colour of the pebbles (resulting from the shocks endured during transportation) is spread all over them. The coincidence of the glaciations and of the corresponding depositions is further documented by the similar size and character of the detritus on the coeval morains and other deposits. This sort of evidence that was studied in particular along the Sava river and along its tributaries in the Ljubljana basin provided the basis for a very detailed classification of the morains and of the corresponding deposits of different age (Šifrer, 1960a, 1961, 1969; Meze, 1964/65, 1969).

The erosion phases that separated fluvioglacial deposits from one another have lately been explained almost entirely by climatic factors (Melik, 1930; Rakovec, 1952; Šifrer, 1959, 1961, 1969, 1969a, Meze, 1964/65, 1966, 1969). The erosion would have taken place — just as after the last Ice Age — when the glaciers started retreating. According to latest findings the lateral and, partly, also the linear erosion continued during the initial stages of the next glaciations (Šifrer, 1969). The evidence for such an evolution is seen, first, in the traces of a wide spread fluvioglacial deposition that have been preserved on broad terraces cut into the solid rock and, second, in the absence of any warm-period types of sediments between the rock and the fluvioglacial gravel on top of it. Sediments from warm periods are limited to areas of local structural subsidence (e. g. in the Marsh of Ljubljana) viz. to larger lakes that persisted in the terminal basins for a long time in the subsequent warm periods. Such large lakes existed between the two glacial periods in the basin of Bled-Radovljica. (The last period is undoubtedly the Würm glaciation, while the question whether the preceding one took place in late Würm or in early Riss period or even — as a separate glaciation — in the Würm-Riss transitional period, is still an open one). The gravel in the deltas of that lake is rounded in a similar way as the recent gravel and much more so than the fluvioglacial gravel (Šifrer, 1969).

Attention should also be drawn to the studies of the wide-spread clay and sand sediments found on the rim of the wide plains filled with fluvioglacial gravel, which were generally considered as lacustrine. The lakes have been formed in areas sheltered from the copious deposition of the glacial streams. More recent research, however, suggests that they are of fluvial or of denudation origin (Šifrer, 1961, 1969; Meze 1966. Firmer evidence of the lacustrine origin of such sediments was produced only for those in the Marsh of Ljubljana, which was studied intensively because it is close to the city and because the pile-dwellings of the prehistorical time were found on the edge of the former lake (Rakovec, 1938; Melik, 1946, where all earlier literature on the marsh is also given; Šercelj, 1966).

It was also possible to establish deep pleistocene erosion (100 to 300 metres) in the valleys outside the area of the immediate impact of glaciation and of fluvioglacial deposition. Six viz. seven terraces were found to be cut into them. The studies of the Alpine area have revealed that the bulky gravel carried by the rivers in that period was of decisive importance for erosion and also that strong erosion and partly lateral erosion took place as well during the periglacial periods while intensive linear erosion took place in the subsequent warm periods. These findings have not been basically modified by studies carried out in other parts of the country although they have contributed significant supplementary information. First of all, it was brought forward that the erosion process which had been started after the latest fluvioperiglacial deposition was far from simple. It was discontinued during the holocene period by several stages of the gravel, sand and clay deposition which were not yet studied enough in detail. These deposits in the valleys along the middle and lower courses of the rivers have not yet been either entirely dissected until the present time. There is no doubt that such processes took place also during the earlier warmer periods, although the sediments of these periods are hardly preserved in any place. It was established that the fluvioperiglacial gravel which was deposited on terraces lies everywhere directly on solid rock. In the locally deposited sands and sandy clays (that are in places intermixed) only the pollens and macro-organic remainings of the northern taiga type vegetation were found. This fact can hardly be explained in any other way than by the continued erosion of the warm periods well into the following cold periods. This erosion has subsequently removed the deposits from the warm periods. It appears that the linear erosion only gradually passed over to lateral erosion. This has happened most probably only during the peaks of the glaciation, when the dryness and the abundant supply of the periglacial detritus from the slopes has led to accumulation in the valleys. The upper parts of the valleys in particular were filled with vast amounts of rock-waste, but much of it was also deposited in the alluvial fans that came into existence where the mountain streams reached the basins. The lateral erosion in the little resistent tertiary rocks that crop out at places was very substantial when the rivers changed their courses across the fans. But even in such periods the linear erosion seems not to have ceased altogether as can be concluded from the fact that the thickness of the gravel cover in the lower reaches of the alluvial fans is rapidly decreasing and, also, from another fact which is a sudden increase of the bed-rock debris within these parts of the fans. It is also possible to make another conclusion on the basis of this evidence, i. e. that the linear erosion was the predominant process during the quarternary period and that even in the periglacial periods it was discontinued only in the upper reaches of the valleys (Šifrer, 1961 b).

The question of the role played by the tectonic movements in the upper pliocene and pleistocene period was also raised. The more recent studies tend to reject the thesis that asummed that the planed surfaces at the summit level of the present relief were formed during a long period of tectonic still-stand close to the sea-level of that time and were uplifted to present heights only by later tectonic movements. The notion of the Dinaric-Alpine area at the beginning of the planation (in the pliocene period) as a landscape of wide gentle forms already at considerable altitude but — on the whole — not yet dissected is more and more gaining ground. In reletion to this notion attention is often drawn to similar conditions that can be observed now in the tropical countries where even at altitudes of some 1000 to 1500 metres no deeper erosion cuts in the relief can be noticed. Because the relief in Slovenia was already substantially uplifted the erosion was started already when the first cool spells and periodic dry seasons began to appear in the late pliocene times and which were responsible for intensive mechanical weathering of the bed-rock, for the selective erosion and for all processes which have contributed to the acceleration of the linear erosion. Also, the preserved planation surfaces as remnants of the older relief can exist at different heights without being necessarily dependent on tectonic movements. A general uplift of the relief is, of course, not denied even for later periods. There were also some local uplifts or subsidences, but also foldings, even of the quarternary sedniments. As far as can be said on the basis of the research carried out until now, these movements were, however, mostly limited to smaller areas (Gams, 1957; Šifrer, 1961, 1964; Melik, 1963; Meze, 1966; Radinja, 1966, 1967). The structural disturbances were proved by conventional methods as well as by the study of the acutal but also entirely theoretical profiles of the rivers (Ilešič, 1951, 1953) and by the study of the marine terraces along the Gulf of Trieste (Šifrer, 1965). The tectonic movements have undoubtedly accelerated erosion. Its intensity was also assesed by some researchers on the basis of information about the intensity of the present processes and by measurements of the corrosion intensity. The studies suggest that the landforms of Slovenia are of a comparatively recent origin (Gams, 1957, 1963, 1967).

Some other phenomena and processes concerning the landforms of Slovenia were also studied. Regular observations of the small Triglav and Skuta glaciers, which are retreating, are being held since 1955. The snow-fields in the Kamnik and the Julian Alps as well as traces of contemporary transformation of landforms in the high mountains above the tree line line were studied in some detail, too (Meze, 1955; Gams, 1961; Šifrer, 1961, 1961a, 1963) and so were the occasional natural catastrophes and their effects: weather storms, avalanches, landslides, slumps, soil erosion, etc. (Melik, 1954a; Gams, 1955; Šifrer, 1962; Sore, 1963; Radinja, 1971).

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